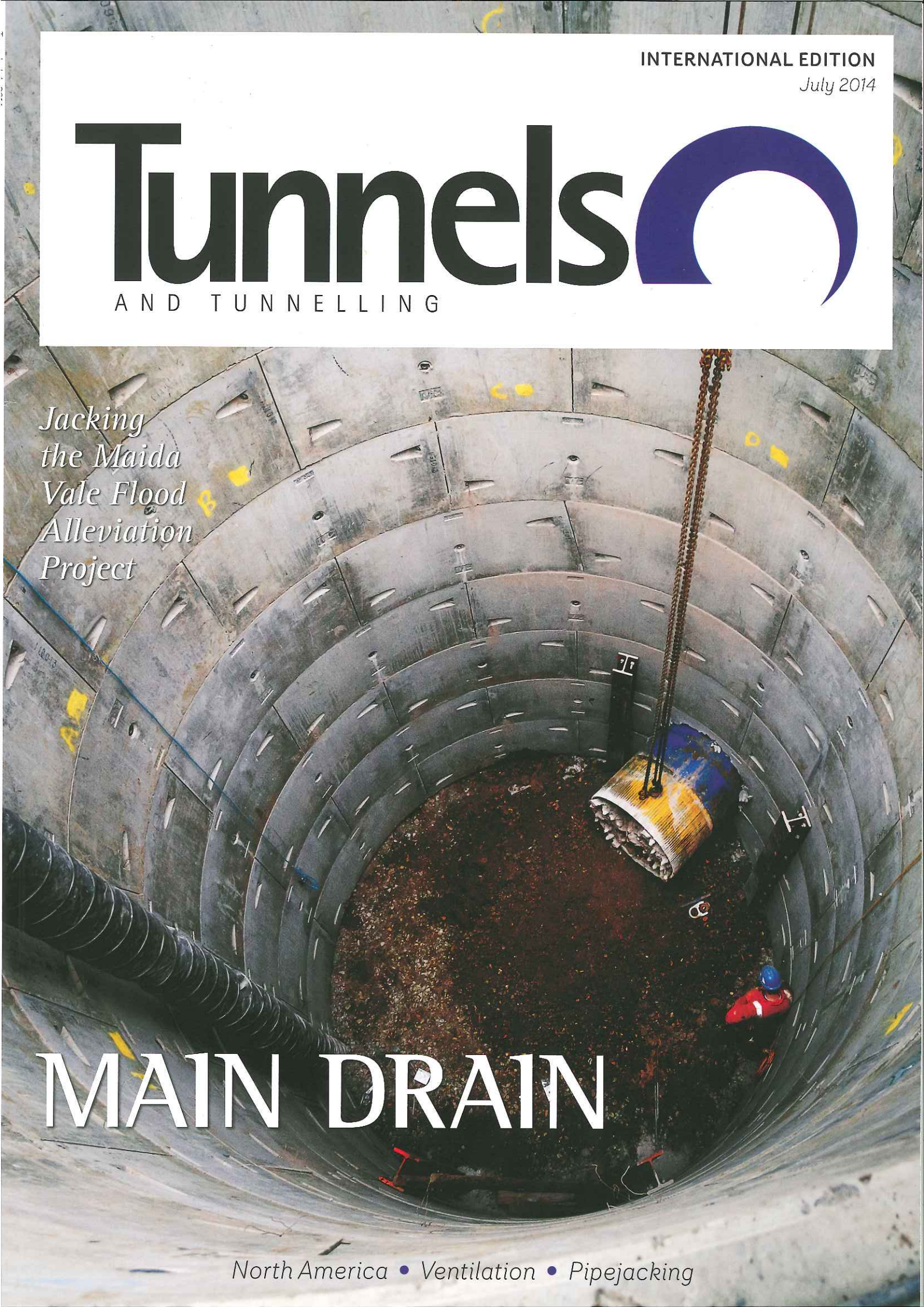
INTERNATIONAL EDITION
July 2014

Tunnels AND TUNNELLING



Jacking the Maida Vale Flood Alleviation Project

MAIN DRAIN

North America • Ventilation • Pipejacking



BETTER TOGETHER

ASULLEN Lionel Messi stood with stooped shoulders next to the award winning German goalkeeper Manuel Neuer in the immediate aftermath of the Fifa World Cup Final. The Argentineans under his captaincy had failed to get even a single shot on target against a victorious German team that had previously pasted tournament hosts Brazil.

Aside from spoof online videos of German beer tankards smashing South American cocktail glasses, it did not take long for articles to start appearing where pundits analyse the German road to victory.

A German businessman from the fashion industry – and friend to the team's management – Christian Hirmer stated that the top team of the tournament would have the best training camp. One purpose-built team training camp (and a trophy) later, and his words carry some weight.

He stressed the importance of teamwork, preparation, and maximising all of the fringe advantages of a team that is comfortable with itself that can make a difference to the balance of play on the night

The tunnelling industry has shown readiness to embrace this ethos in the past, and looks set to continue to do so on key projects.

Last year Tunnels visited site with TBM manufacturer Terratec's field service engineers in Delhi. This predominantly Thai workforce was quartered together in the city, complete with their own resident chef for home comforts. On site, a soundless system of gestures and waves quickly and safely carried out machine assembly at the bottom of a launch shaft. There was something almost eerie about the silent, albeit impressive procedure.

The tunnelling market in India has placed great importance on international involvement with local counterparts to deliver projects, and it is not an anomaly.

Qatar Rail mandated that large works contracts for the Doha Metro will only be awarded to consortia that comprise both local and international parties. The idea is that giant multinationals would provide state of the art railway building knowhow, with local procedural and cultural finesse being contributed by the smaller party.

Just as local investment is a boost for the people of Santo Andre, the nearest village to Germany's Brazilian training haven, this is a boon to the local Middle East contractors, but it makes sense from the client's point of view also. Skills acquired during construction will allow for locally performed maintenance upon completion.

With lump sum contracts and a degree of relatively obscure ground conditions among the karstic limestone. The consortia would do well to foster good teamwork and understanding within their ranks.

The ability of the German team to pull together in a high stakes situation, and their eagerness to support fellow teammates won them the ultimate victory in Brazil.

These same attributes applied to any tunnelling job can overcome the most complex obstacles

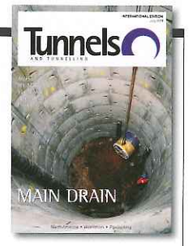
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What do you think? Send your views to the editor and join the debate

Alex Conacher
Deputy Editor



Cover
The Maida Vale flood alleviation project in northwest London features pipejacking technology



Next issue
In the next issue Tunnels and Tunnelling looks at the Middle East tunnelling market, which with projects such as the Doha Metro throwing around previously unheard-of numbers of TBMs, seems set to be the most exciting region in global underground engineering

This month...

20 YEARS AGO

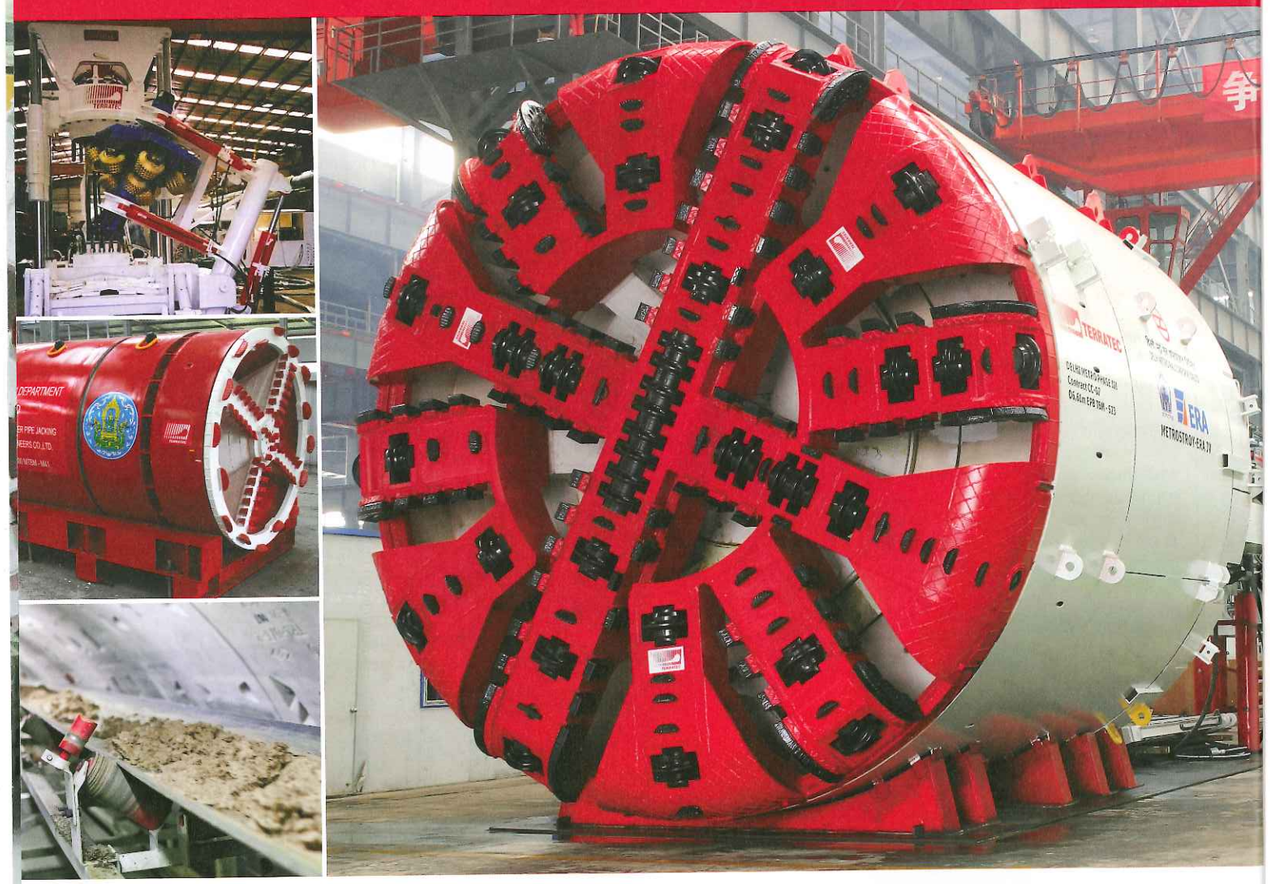
The Cleuson-Dixence hydroelectric project in western Switzerland should begin construction this month, aiming to increase the electricity supply to the region to meet the three per cent rise in winter residential demand. It should be operational by winter 1998/99. The scheme comprises a 15km-long water tunnel, surge tank, 4.3km-long inclined pressure tunnel and an underground powerhouse. Water from the reservoir will flow via the tunnel to the generating plant in the Rhone Valley, producing 1,180MW. Two Robbins double shield TBMs, of 4.83m and 5.83m have been acquired for the job, the smaller of which will face grades of up to 64 per cent.
Tunnels and Tunnelling, July 1994, p.11

30 YEARS AGO

Fifteen people have been killed in an explosion at an underground water pumping/valve station at Abbeystead in the northeast of England. They were in a party of people being given a tour by the owners, the North West Water Authority. The cause of the explosion is so far unknown, but it has been suggested that methane gas was present in the pumping station. An official investigation is being carried out by the UK Health and Safety Executive. The Lune-Wyre Water Transfer Scheme, opened by the Queen in 1980, was designed to transfer up to 280Ml of water per day from the River Lune via the 6.6km-long Wyresdale Tunnel to the River Wyre which is at a higher level.
Tunnels and Tunnelling, July 1984, p.10

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TERRATEC

News

7 *World news*
The latest project updates, announcements, and tunnelling advances from jobsites all around the world

20 *Business news*
Corporate and personnel changes, key decisions and financial news from global tunnelling companies

North America

23 *The Seattle saga*
Nicole Robinson, Americas editor
After six months of tunnelling standstill, construction is starting on an access shaft to repair the TBM mining the SR 99 bore in Seattle, the largest TBM in the world

28 *Forming a solution*
Ben Roberds, Redpath
Eric Gemin, Redpath
Engineers from Redpath describe the top heading and bench excavation method for the Waneta Expansion Project, and the challenges and benefits of using a self-advancing tunnel form on a 17 per cent slope

34 *Observe and report*
Joseph Sopko, Moretrench
Robert Chamberland, Moretrench
The Southeast Collector Sewer under excavation in York requires 18 different shafts. Groundfreezing became imperative for the project at a TBM launch site when unanticipated boulders hindered slurry wall installation

Technical

38 *Clear air, clear conscience*
Petr Pospisil, Pospisil & Ilg
Ludwig Ilg, Pospisil & Ilg
Limited resources and administrative uncertainty can throw up some difficult safety decisions. The directors of Pospisil & Ilg Associated Engineers provide some advice

Inisght

53 *Bangkok metro pipe roof installation*
Adrian Greeman, technical journalist
Bangkok's metro system construction is making innovative use of pipejacking for the roof of a new underground metro station

48 *Maida Vale Flood Alleviation Project*
Pipejacking is a key part of a flood alleviation project which is set to protect hundreds of properties in northwest London

51 *Cutting carbon*
A new carbon calculator can now be used to show the benefits of pipejacking versus open cut construction



Contributors

JOSEPH SOPKO
Joe graduated from Michigan State University in 1980 with a BS in civil engineering, earning his Masters in 1983 and doctorate in 1990. He joined Moretrench in 2010 as regional manager for its Midwest operations. He has over 30 years of experience in geotechnical construction, particularly for frozen earth excavation support. With his colleague Robert, he reports on work on the Southeast Collector Sewer being excavated in York, Canada. Read him in this issue on page 34

ROBERT R. CHAMBERLAND
Robert is a Project Engineer at Moretrench American Corporation. He has assisted Dr. Joseph Sopko on numerous freeze jobs throughout North America since 1997. In this issue the two work together again on a paper discussing new applications of ground freezing in underground construction. With his colleague Joe, he reports on work on the Southeast Collector Sewer being excavated in York, Canada. Read him in this issue on page 34

ADRIAN GREEMAN
Adrian is a former editor of Tunnels and a longstanding regular contributor. A freelance technical journalist, he produces articles for a range of subjects but is primarily focused on international civil engineering projects, and has written for a number of leading titles. In this issue he reports from the Bangkok Metro, where a pipejacked roof will provide support above a new station for the city's network, which seeks to complete a circular route. Read him on page 53

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Capitol Hill Station, Seattle, USA

Kevin Whalen, Superintendent
Turner Construction, Seattle

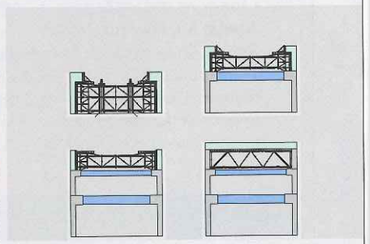
"Working in collaboration, PERI and Turner Construction designed the Traveling Mono System which has met scheduling and budgetary constraints. We've increased the level of safety for our workers as well as reduced the number of man hours required to set up traditional formwork systems. This system was specifically designed to pour concrete from the ground to the roof giving us ability to maximize our labor force and allow subcontractors to work beneath the system, all while improving on the quality of the finished product."



The formwork solution is based on system components of the VARIOKIT engineering construction kit. The traveler system for the bottom level is also used in the upper levels.



The VARIOKIT traveler system rolls from one section to the next on rails after each pour, without the formwork having to be broken down and reassembled.



The three levels of Capitol Hill Station have been poured one after another – using a clever designed traveler system that is moved on rails from one pouring section to the next.

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THOMSON LINE BREAKS GROUND

Singapore A groundbreaking ceremony officially launched construction of the Thomson MRT Line in Singapore on 27 June.

Scheduled to open in three phases in 2019, 2020 and 2021, the 30km north-south line will run entirely underground from Woodlands North to the Central Business District and Marina Bay.

It will largely parallel the existing North-South Line, providing an additional 60 per cent capacity to help relieve crowding along the corridor.

The Thomson Line's 22 stations will include six interchanges connecting with all five existing metro lines, and daily ridership is predicted to reach 400,000.

Land Transport Authority has now awarded 22 of the 25 major civil contracts for the line, with the remaining three to be awarded by the end of this year.

Ground-freezing construction techniques are to be used on the metro network for the first time, to prevent water seepage during tunnelling at Marina Bay where the Thomson, North-South and Circle line tunnels will intersect.

Technically, ground freezing is to freeze the ground to turn the ground water into ice, to form ice wall, so that to facilitate the construction to solidify the ground and to facilitate the construction of the tunnel. This will prevent water from seeping in and weakening the soil.

"The Thomson Line marks yet another milestone towards realising our Land Transport Master Plan's vision to double the length of our rail network", said Minister for Transport Lui Tuck Yew at the groundbreaking ceremony.

"When this is achieved by 2030, our MRT system would be comparable in network density to New York and London."

In the long term, the Thomson Line will be linked to Johor Bahru in Malaysia via a cross-border rapid transit link from Woodlands North station.

Hochtief-Zublin JV secures Cityringen contract

Denmark Hochtief, together with Züblin, signed a EUR 150M (USD 203.15M) contract with public transportation company Metroselskabet to expand the subway network in Copenhagen, the company announced on June 11.

The tunnelling project is part of the Cityringen, or City Circle Line, in the Danish capital. In addition to construction of a total of more than 3.5km of tunnel, the project also comprises the turnkey delivery of the Nordhavn subway station. To this end, the joint venture which consists of Hochtief Infrastrucure Nordic branch and Züblin will mine two approximately 1,800m- and 1,600m-long tunnels TBM.

Beside the roughly 80m-long Nordhavn subway station, the joint venture will also construct a small tunnel and a ramp structure, a service shaft/emergency exit and a pedestrian transfer tunnel to the adjacent, already existing S-train urban rail station Nordhavn. This will provide the area at Copenhagen's northern harbour with a link to the capital's subway ring while making it possible to switch directly between the transportation systems.

"With this project, we continue to grow systematically in the Scandinavian infrastructure market and thus go on positioning ourselves as a strong provider for the expansion of modern and sustainable transportation infrastructure in Europe," said Wilfried Rammler, general manager of Hochtief Infrastructure.

The works on the project will start as early as in June this year and will be completed in 2019.

Worker dies on Indy Deep Tunnel project

USA A crew member on Indianapolis' Deep Rock Connector Tunnel project died Friday in the early morning while working underground, project owner Citizens Energy reported.

William "Isaac" Simpson, 25, was employed by the Shea-Kiewit JV contracted to build the tunnel project. The cause is still unknown.

"Our hearts go out to the worker's family. Thank you for your patience as we gather the details of this incident," Citizens Energy said in a statement issued Friday. The Indiana Occupational Safety and Health Administration and police are investigating.

Black & Veatch and AECOM win DTSS contract

Singapore A joint venture between Black & Veatch and AECOM has been selected by PUB, Singapore's national water agency, to provide engineering services for Phase Two of the Deep Tunnel Sewerage System (DTSS), it was announced June 3.

Freeing up land for other higher-value developments, supporting the production of NEWater, improving energy efficiencies and potentially leveraging the water-energy-waste nexus are some of the key sustainability goals of DTSS Phase 2.

"We have assembled a compelling joint venture team of world-class local and global experts, who look forward to delivering a sustainable infrastructure solution," said Michael S. Burke, Aecom president and CEO. "We are honoured to be a part of the DTSS project, which will enhance Singapore's water sustainability and resilience – solidifying its place as a leader in the global water industry."

DTSS Phase 2 will extend DTSS to the western side of Singapore through a 30km-long South Tunnel, some 70km of link sewers, the Tuas Water Reclamation Plant (WRP) and a also an estimated 12km-long deep sea outfall. The entire DTSS will result in a 50 per cent reduction in land taken by used-water infrastructure with three centralised collection and treatment points: Changi WRP in the east; Kranji WRP in the north; and Tuas WRP in the west.

A NEWater factory will be integrated with the Tuas WRP and contribute to Singapore's long-term goal of increasing NEWater production to meet up to 55 per cent of its total water demand.

In addition, working with Singapore's National Environment Agency, an Integrated Waste Management Facility will be co-located at the Tuas WRP site. This offers potential opportunities to integrate used-water and solid-waste treatments to maximise energy and resource recovery.

The B&V+Aecom JV will conduct a feasibility study and preliminary design as part of the first stage of the project.

As the lead consultant, the team will programme manage the delivery of DTSS Phase 2 in the second stage of the project. Supporting Black & Veatch and Aecom will be Ramboll, a leading consulting engineering company from Denmark and KPMG.

Tunnel for Baku-Tbilisi Kars rail line built in Turkey

Turkey Construction of Baku-Tbilisi-Kars (BTK) railway line is advancing in accordance with the new schedule, according to a 27 May news story by Baku-based Azerbaijan Business Center.

Azerbaijani Deputy Transport Minister Musa Panahov was quoted as saying that construction of the Turkish part of the tunnel on the Georgian-Turkish border has been completed fully.

"This 800m section of the tunnel is now fully operational, and work is being conducted on almost 1.5km Georgian section. The works will be fully completed in 2015 that will enable (concerned countries) to start commercial operation of the railroad," Panahov said.

The work on the Georgian section began in the fall of 2013, and is being conducted by Turkish companies, which had built the tunnel from the Turkish side.

"In 2014 a work train will be put into operation via the new railway. This will allow start of work on preparation for the launch of commercial operation," Panahov said.

The start-up of the work train is scheduled for October. Delays in the construction of the railway tunnel are linked with changes in the intersection point of the Georgian and Turkish sections, that increased the total length of the connecting tunnel.

"The process of government change and structural reforms in Georgia justifies reason for the delays in implementing the project," Head of Azeryolservis JSC (road transport infrastructure) of the Azerbaijani Ministry of Transport Javid Gurbanov told journalists in late February... It led to the delay in the construction of the railway tunnel on the Georgian-Turkish border, he said. Gurbanov said despite the fact that building the tunnels has been completed in Turkey, the work in Georgia's territory has started recently due to the above-mentioned reasons.

The BTK railway is a regional rail link project that connects Azerbaijan, Georgia, and Turkey. After commissioning of the railway, mutual trade between Azerbaijan, Georgia, and Turkey will increase significantly, with the total volume exceeding USD 10bn per year.

Designer appointed for major upgrade of Auckland CRL

New Zealand Mott MacDonald, as part of an integrated team, has been appointed to undertake the reference design for the NZD 2.86bn (USD 2.43bn) upgrade of the City Rail Link (CRL) in Auckland, New Zealand. Mott MacDonald is developing the project on behalf of Auckland Transport, while team members also include Aurecon, Jasmax and Grimshaw.

The upgrade includes the construction of two 3.4km long twin tunnels. These will enable the extension of the existing rail line underground through Britomart, to Albert, Vincent and Pitt Streets with additional city centre stations.

Mott MacDonald and the team are leading the design of the stations and the mechanical and electrical systems. Sustainability, system assurance, human behavioural factors and people movements will be figured into the design which will meet reliability, availability and maintainability requirements, the company stated.

Peter Taylor, Mott MacDonald's project director said: "CRL is the most significant improvement to Auckland's transport network since the opening of the Auckland Harbour Bridge. It will help shape the city's future, linking to the existing rail system to support economic and population growth, helping Auckland become a globally competitive city.

"Mott MacDonald first began working on the CRL in February 2012, when the team led station designs and produced concept designs. Where possible the project is below city streets to reduce the need for effects for property owners and city heritage buildings."

GOTHENBURG IMMERSED TUBE TUNNEL CONTRACT

Sweden Züblin Scandinavia has been named as leader and main shareholder of the design and build contract for the Marieholmstunnel project, a 500m long immersed tunnel consisting of 30m wide by 10m high elements, that passes under the river Göta älv in the city of Gothenburg.

The contract, which also comprises the mechanical and electrical works and has a total contract value of some EUR 170M (USD 231M), was signed on 4 June. Owner of the project is the Swedish road and railway authority Trafikverket, to which the tunnel is to be handed over in October 2020.

Marieholmstunnel is a road tunnel consisting of three lanes in either direction with a service tunnel in the centre and a designed lifetime of 120 years. Züblin will construct three tunnel elements of 100m in length each on site in a drydock and immerse them at their final location in a trench dredged into the river bed. On either side of the immersed tunnel section, cut and cover tunnels will be built in deep excavation pits continuing in ramp and trough sections.

Züblin states that special consideration will be given to the environment, for example the flora and fauna of the Göta älv River, during all phases of construction. The installation of all mechanical and electrical systems also forms part of the contract, which includes an option to operate and maintain the tunnel for five years after completion.

The project will start just after the handover of Trafikverket's Söderströmstunnel in Stockholm, a project of similar size and complexity executed by Züblin also as an immersed tunnel.

Breakthrough on Black River Tunnel project

USA A Robbins double shield TBM broke through at the Black River Tunnel Project in Lorain, Ohio late last month. The project marks the first use of Onsite First Time Assembly (OFTA) in the US, which Robbins stated shaved valuable time off of the project timeline. The machine and continuous conveyor system were assembled at the jobsite with the help of Robbins field service technicians, rather than in a shop. The TBM was launched on November 18, 2013, just three months after assembly began.

"The machine performed quite well," said Gregg Rehak, tunnel supervisor for contractor Super Excavators. "Now we have to remove the TBM, which will take about four weeks; then rebar tying and concrete pouring can start."

Once finished in 2015, the tunnel will have a storage capacity of 42Ml per day.

GOWANUS CANAL TUNNEL ACTIVE

USA The New York City Department of Environmental Protection (DEP) reactivated the Gowanus Canal Flushing Tunnel after a full rehabilitation and upgrade worth USD 177M that began in 2010, it announced May 29.

The rehabilitation work also included draining the 1.2-mile-long, 12ft diameter tunnel and inspecting and repairing its brick-lined interior. The activation of three submersible turbine pumps is bringing up to 252 million gallons of oxygen-rich water to the head of the Canal each day, or roughly 30 per cent more than was possible before the upgrade. The infusion of fresher water provided through the Flushing Tunnel has already increased the dissolved oxygen content of the water in the Canal which will dramatically improve its aesthetics and provide a more suitable habitat for plant and aquatic life.

In addition to the Flushing Tunnel, DEP is completing a rehabilitation and upgrade of a wastewater pumping station at the head of the Canal that will reduce sewer overflows during heavy rain storms.

In June, DEP reactivated the pump station which will allow it to send up to 30 million gallons of wastewater to the Red Hook Wastewater Treatment plant each day, a 50 per cent upgrade over its previous capacity. DEP will continue site and building improvements over the summer, including the removal of the temporary oxygenation system, with work on the USD 177M projects expected to be completed this fall.

"The USD 177M upgrade of the Flushing Tunnel is a significant milestone in the City's efforts to improve the health and cleanliness of the Gowanus Canal," said DEP commissioner Emily Lloyd. "Over the summer we will also complete an upgrade to an important wastewater pump station and begin the installation of hundreds of curbside gardens in the surrounding neighborhoods, all of which will help to improve water quality in the Canal."

After Hurricane Sandy, construction plans for the Flushing Tunnel, wastewater pump station and the support buildings were altered to include resiliency measures such as raising the control room floor and its critical electrical equipment, flood-proofing the service building and installing a dyke wall and mechanical flood gate. As part of the upgrade, the Flushing Tunnel will now operate around the clock, including at low-tide, when the Canal water is at its most stagnant. The system of three pumps also provides redundancy that will ensure that the tunnel remains operational during future maintenance and repairs.

The Gowanus Canal is a nearly two mile long man made waterway that was built in the 1860s to facilitate commerce in western Brooklyn. The Canal runs from New York Harbor northeast through the Red Hook, Carroll Gardens, and Park Slope neighborhoods where it dead ends at Butler Street. Over time, commerce in the area grew but the Canal and its environs were left with a legacy of industrial contamination. In addition, with limited natural movement of water, the Canal became stagnant and polluted.

British Prime Minister welcomes construction job boost

Great Britain Prime Minister David Cameron joined Balfour Beatty to announce that thousands of construction jobs are to be safeguarded through a GBP 1bn (USD 1.7bn) investment scheme launched by the construction group.

Designed to support those in skilled building roles, Balfour Beatty has revealed that the sum will be spent on contracts with small and medium-sized businesses across the UK.

The GBP 1bn (USD 1.7bn) spend will contribute to supporting some 200,000 jobs within smaller businesses, 50,000 more than in 2013.

Balfour Beatty's supply chain workforce could swell to 200,000, in light of the proposals.

Cameron said: "Giving businesses the confidence to invest and create jobs is a key part of our long term economic plan.

"Balfour Beatty's commitment to spend a record GBP 1bn on small and medium sized businesses this year is very welcome evidence that this plan is working - supporting thousands of jobs within small and medium businesses, which will give hard-working people economic security for the future."

Nicholas Pollard, CEO, Balfour Beatty Construction Services UK, added: "We are delighted the Prime Minister could be with us today to celebrate our GBP 1bn (USD 1.7bn) spend with small businesses this year, 98 per cent of which are British companies.

"Small businesses create local jobs and apprenticeships and they are the innovators, engineers and 'exporters' of the future.

"We are committed to supporting them so that we can build a better Britain together; leaving a lasting legacy in the communities we touch across the UK."

Japan plans a subsidy system for new maintenance rules

Japan The Japanese government has plans to create a new subsidy system in 2015 for large-scale repairs of road bridges and tunnels by municipal and prefectural governments, according to an local media reports. The work will be required under new legislation. The Land, Infrastructure, Transport and Tourism Ministry, which is considering subsidising half of the costs for such repairs, wants to include related expenses into its budget request for the fiscal year from next April.

Roads and other infrastructure built in Japan during its high economic growth period need renovation, but repair costs weigh heavily on financially strapped local governments.

The ministry concluded that financial assistance is necessary for appropriate maintenance of such infrastructure to ensure safety. Because of fiscal woes and a shortage of engineers in rural areas, municipalities have taken makeshift measures, such as road closures instead of maintenance.

A survey by the infrastructure ministry in 2012 indicated that about 90 per cent of municipal governments fear budget shortfalls will cause safety problems for infrastructure under their management.

The ministry has stepped up measures against ageing infrastructure in response to the fatal accident in the Sasago tunnel in Yamanashi Prefecture in December 2012, which was caused by falling ceiling panels.

Starting from July, the ministry will require administrators of all road tunnels to conduct on-site safety inspections every five years. About 40 per cent of bridges throughout the country and about 30 per cent of tunnels will be more than 50 years old in 10 years from now.

CORROSION CONTRACT AWARDED FOR EURASIA TUNNEL PROJECT

Turkey Intertek has secured a contract to provide corrosion services for the Eurasia Tunnel Project in Istanbul, which will result in the construction of an undersea highway connecting Asia and Europe for the first time.

The agreement will see Intertek supply four types of corrosion sensors to monitor the reinforced steel within the concrete tunnel. The company will also provide instrumentation and installation support for the operation of these probes, which will ensure the continued integrity of the materials within the structure.

Intertek was awarded the contract by the Yapi Merkezi and SK Engineering and Construction joint venture, the main engineering, procurement and construction contractor of Avrasya Tüneli Isletme Insaat ve Yatirim AS (ATAS). Tom Gooderham, instrumentation manager at Intertek Production and Integrity Assurance, said: "Being involved in an infrastructure project of this scale is testament to our expertise in condition monitoring and we look forward to working with ATAS to support the future maintenance of this tunnel which will significantly improve transport links in Turkey.

"Our work will aid the early detection of corrosion and provide health status information on the infrastructure. This will be used to determine when to switch on the cathodic protection systems to prevent corrosion occurring and help maintain the tunnel for years to come."

Upon its completion, the highway will connect the districts of Zeytinburnu and Kadiköy and cover a total of 14.6km. This will alleviate the most intense traffic pressure points in Istanbul, allowing for faster links between the city's Asian and European sides.

Construction commenced in early 2013 and the Eurasia Tunnel Project is expected to be complete in 2017. The undersea section will be 5.4km long and two stories high, with surrounding roadworks supporting connections to the new tunnel.

Lesotho water project - phase II to be completed by 2023

South Africa Development Authority expects the SAR 11.2bn (USD 2.99bn) second phase of the Lesotho Highlands Water Project to be completed by 2023, the project's executive manager, Mark Matchett, announced on 23 June, according to the South African Government's official News Agency.

The massive joint project between South Africa and land-locked Lesotho will generate hydroelectric power for Lesotho while increasing the volume of water transferred to South Africa from the current 10 billion cubic metres to about 15 billion cubic metres a year.

The first phase of the project, which is comprised of a series of dams, hydropower stations and tunnels between South Africa and the mountainous, Lesotho was funded by the World Bank and completed in 2004.

The second phase will involve building the Polihali Dam in the Mokhotlong district, which is located in the northeastern part of Lesotho and includes both the highest terrain in the Maloti mountain range and the source of the Senqu River, Lesotho's primary watershed.

A new tunnel will also be built from the Polihali Dam to the Katse Dam, along with associated new hydropower features and other advanced infrastructure.

Speaking at a briefing session in Johannesburg, Matchett said: "We are about to embark on a procurement process. This will run for a fairly intensive six to nine-month period, and during this time we hope to have procured most of the design contracts.

"Towards the middle and the end of next year, we hope to be in a position to start procuring contracts for the construction works."

Matchett added that design work on the dam and the tunnel is expected to start during the first or second quarter of next year, while construction is expected to commence during the third or fourth quarter.

Matchett said the new dam could reach its minimum operating level by 2022, if there were sufficient rain, and "if all goes well [...] we are looking at completion by the year 2023."

Work on environmental studies, mitigation plans, resettlements and compensations has already begun and should be complete by the end of October or November.

Thai firm proposes Phom Penh parking lot and market

Cambodia Cambodian government officials met in Phom Penh on 26 June with representatives from a Thai company proposing to build an underground parking lot and market adjacent to Daun Penh district's Phsar Chas.

Deputy municipal governor Chreang Sophann told local news reporters that the proposal by the company, Trade International, is under consideration.

"I support all kinds of investment in the city but we must first study the impact," Sophann said.

"For Phnom Penh to have an underground market and parking lot would be attractive to investors and show the leadership of the government, while it would improve the beauty of the city and create more jobs."

Phnom Penh Municipal Hall spokesman Long Dimanche stressed that the plan is still at the discussion stage. "It could benefit the city a lot, but we must first study the documents and see if we think the plan is good," he said.

The Old Market area, west of the Night Market, has long been touted as a potential neighbourhood for redevelopment.

According to reports by state-run media, the Municipal Hall announced in January last year that it would build an eight-storey car park on the site, relocating the market to two underground floors.

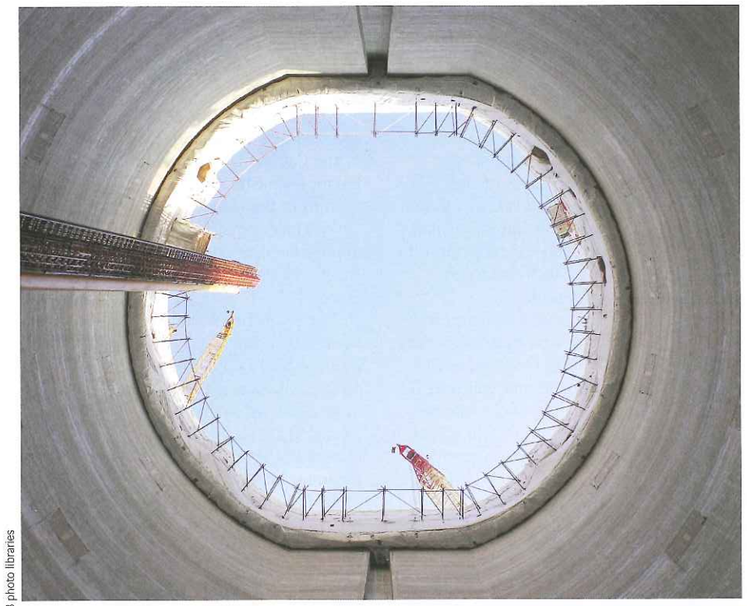
Wuhan City inaugurates Line One extension

China The Chinese city of Wuhan inaugurated the latest addition to its metro network on 28 May, when commercial services began running on the 5.7km northern extension of Line One from Dijiao to Hankou North.

With the opening of the three-station extension, traffic on Line One is expected to reach 560,000 passengers per day by 2016.

Peak services operate at nine minute intervals on the extension and every 10 minutes at other times.

The opening of the extension takes the total length of Line One to 34.5km with 28 stations.







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Tunnel mulled for Baku to ease traffic congestion

Azerbaijan Construction of an underground tunnel down the Neftchiler avenue underneath the Caspian Sea has been proposed in General Plan of Baku (capital city of Azerbaijan), in order to prevent traffic jams in the downtown Baku, Hidayat Rustamov, Department Chief of Azeryolservis OJSC (the authority responsible for improvement of road infrastructure) told Azeri Press Agency (APA) on 14 June.

He noted that the tunnel along the seabed will connect to the Baku Ring Road, and thus allow automobiles to move east and west of the city from the north and south without entering the downtown Baku.

However, the State Committee for Architecture and Urban Planning doesn't give consent to the Baku Bay Sea Bridge project. Head of the Department of International Relations and Information under the Committee Jahangir Gojayev said that in the first place Khazri wind (a name of the cold north Caspian Sea wind) doesn't allow automobiles to constantly move on the Baku Bay Sea Bridge.

"Besides that, it will deform the view of the Baku Bay. At the same time, construction of the underground tunnel calls for a relatively less amount of funding. A proportion of about 0.9km of the underground tunnel will be above the surface. This part will be constructed from the sea port to Nobel avenue," Gojayev said.

The tunnel will start in Bayil, several hundred metres away from the Bahram Gur monument, and end near the old building of the Marine Port. The tunnel will adjoin the side of the Boulevard and be covered by soil, and therefore, the width of the Boulevard will be enlarged by 20 to 30m.

Unlike the bridge, the length of the tunnel is going to be approximately 3.6km.

The population density in Baku has brought about the traffic congestion in the capital. About 730,000 out of 1,300,000 vehicles in the country have concentrated in Baku, according to Rustamov.

Bangladesh ministry asked to study feasibility for underground railway

Bangladesh The cabinet purchase committee on 15 June directed the communications ministry to conduct a feasibility study for an underground railway in Dhaka to ease traffic congestion in the capital city of Bangladesh.

The directive came at a meeting of the committee at the Cabinet Division, with Finance Minister A.M.A. Muhith in the chair.

The meeting approved appointment of consultants for the Dhaka Mass Rapid Transit (DMRT) project.

The Asian Development Bank (ADB), Japan International Cooperation Agency (JICA) and China have expressed interest in financing the underground railway in the capital, Planning Minister A.H.M. Mustafa Kamal told a press conference at the auditorium of the National Economic Council.

After conducting the feasibility study, the government will pick the strategic partner for construction of the underground railway, Kamal said. The purchase body endorsed the appointment of a consultant to enhance the institutional capacity of the Dhaka Mass Transit Co. Ltd. A joint venture company led by Japan-based Oriental Consultancy Co. has landed the job.

The Dhaka Mass Transit Co. is implementing the metro rail project.

Construction of Haicang Undersea Tunnel expected to start by year's end

China The construction on the undersea section of the Haicang Undersea Tunnel is expected to officially start at the end of this year after the completion of the connecting portions in Xiamen's Haicang and Huli Districts, according to local media reports on 13 June.

With a total investment of CNY 6bn (USD 1bn), the Xiamen western tunnel will have a total length of 9.56km, and its tunnel length will reach 6.34km. It is designed to be a standard two-way six-lane freeway with a speed of 80 km/h.

Haicang Undersea Tunnel, also called the Second West Tunnel, will be the second undersea tunnel in Xiamen, after the Xiang'an Undersea Tunnel, the first of its kind in mainland China.

The preliminary scheme showed that Huli District and Haicang District would be the two points of junction for this project, according to reports.

The tunnel will then continue to go beneath the ground along Xinghu Road, and climb out near Huoju Bei Road. The Xiamen western tunnel will run across Huli District, and connect with Jiahe Road, Chenggong Avenue, Huandao Road and other roads.

The Haicang Undersea Tunnel should help alleviate the heavy traffic load of Haicang Bridge and greatly reduce the traffic distance between the Haicang bonded port area and Xiamen Island upon its opening in 2017.

Lowari tunnel widening declared nearly halfway complete by officials

Pakistan Work on the Lowari Tunnel Project on Nowshera-Dir-Chitral Road (N-45) is ongoing and so far over 45 per cent of work on tunnel widening has been completed, while over 40 per cent of total civil works required have been completed.

An official of the Ministry of Communications told the official Associated Press of Pakistan (APP) news agency in Islamabad on 13 June that overall progress of the tunnel project is about 33 per cent.

An earlier APP story quoted local officials as saying that the project would be completed by October 2017.

Lowari Tunnel is an 8.75km long under-construction road tunnel having a 7.1m diameter and situated in the Khyber-Pakhtunkhwa province of Pakistan.

PERU PLEDGES USD 2BN FOR RAIL TUNNEL

Peru Peruvian officials announced plans to allocate USD 2bn to build Trans-Andean rail tunnel for the country's Central Railroad, according to the Transport and Communication Ministry (MTC).

Peruvian Transport and Communication Minister, Carlos Paredes told local media the preliminary infrastructure studies are in the final phase and expected to be complete before the end of the year.

Thus far studies reveal that an estimated investment of nearly USD 2bn is required to construct a tunnel covering a length of 7km to pass through Peru's Andes mountain chain. It would be the country's longest tunnel, and circumvent the Ticlio Pass, located 4,758m above sea level on the Andean side of the Lima region.



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UNDERGROUND PARK PLAN FOR UAE

UAE A new underground park is expected to be built in Abu Dhabi where families could enjoy get-togethers and picnics in a cooler environment.

Designed by London-based Heatherwick Studio, the 20m-high shaded Al Fayah Park will offer visitors cafes, play spaces, a library, pools and streams as well as date palms and community vegetable gardens.

According to Heatherwick, the studio was asked to "re-conceive" a major piece of public land in Abu Dhabi. Following the rapid pace of the city's recent development there was a desire to provide a local park as a public space devoted to the well-being of the people of the city.

Heatherwick said that by creating partial shades for plants, the canopy aims to reduce the amount of water lost to evaporation and so will improve the park's energy efficiency and sustainability.

British daily newspaper 'The Telegraph' said the construction of the Al Fayah Park is likely to begin in 2015 and due to be completed in 2017.

The London-based designer Thomas Heatherwick has previously designed a great number of landmarks including London Bus, Olympic Cauldron, London's Garden Bridge among others. Heatherwick said designing a park in the desert presented the studio with a series of challenges, the most serious of which was how to provide protection from the heat for visitors as well as vegetation. Offering a place for relaxation and leisure for those using it, the park also needed to be energy efficient and sustainable in its use of water to irrigate vegetation.

It said the existing public space evoked the style of a European park by covering the desert with a blanket of grass. However, counteracting evaporation caused by the intensity of the sun required a significant amount of purified water to irrigate it, produced industrially from salty sea water using a costly and high energy consuming desalination process. Heatherwick Studio is recognised for its work in architecture.

TBM refurbishment facility planned for Malaysia

Malaysia China Railway Tunnelling Equipment Co. (CRTE) said it is looking forward to setting up a Tunnel Boring Machine (TBM) refurbishment facility in Malaysia and has budgeted around MYR 20M (USD 6M) for this purpose.

Two of the TBMs excavating a portion of the Sungai Buloh-Kajang (SBK) Line of the Klang Valley MRT will be refurbished, according to CRTE chairman Li Jianbin.

"We prefer to refurbish them in Malaysia," said Li, 52, who has more than 25 years of experience working on tunnels. He said Malaysia is a natural choice due to the fact that it is surrounded by MRT projects that use mainly new machines.

For example, Singapore requires all metro projects to use only brand new machines. Even the tunnelling contract for the SBK Line had the "brand new only" component built into the requirement for tenders.

Indonesia is starting with its metro tunnelling drive, with the launch of the Jakarta metro construction recently. All these make for the availability of many TBMs that still have some life left in them. The refurbishment business outside of China fits in nicely with CRTE's aim to transform itself into a global TBM supplier.

It is already China's largest TBM manufacturer, but competition at home is stiff even though there are more than 700 TBMs of all shapes and sizes running in the republic on any given day.

"We are looking at renting or acquiring a piece of land ranging from 3ha to 4ha within a free trade zone," said managing director of CTE, CRTE's international division, Don Hall.

CTE initially found a piece of land at the Port Klang Free Zone (PKFZ) located in Pulau Indah. The size was right, and so was the rental.

However, the soft ground scuttled the deal to set up Malaysia's first TBM refurbishment workshop that could see a workforce of up to 20 skilled technicians at work. The free trade zone facilitates the entry and exit of TBMs needing refurbishment as well as sending them to their onward destination, without going through tedious Customs paperwork.

"The site in PKFZ would have been great for us except that the ground was too soft. Our machinery imposes exceptionally high loadings of at least 300t per square metre on the floor."

CTE is still interested in making its venture work in Malaysia, and is on the hunt for a site as the date draws closer for its two TBMs to be recovered from the ground at the upcoming Pasar Seni MRT station by August and September, respectively.

Crossrail launches its smallest TBM...

Great Britain Crossrail has launched its smallest tunnelling machine Molley to build a new Thames Water sewer in west London. The 1.45m diameter TBM is 3.3m long. Molley will build a new 564m long tunnel to divert a section of the Great Western Road Sewer between Westbourne Park station and Basing Street, under Tavistock Road.

The sewer needs to be redirected as the Crossrail project will be lowering the mainline tracks near Westbourne Park to accommodate its trains running into Paddington, so impacting on the existing sewer. The TBM is too small to accommodate workers so is controlled remotely from the surface. Works are scheduled to be completed by the end of the year.

...while Ellie breaks through into Stepney Green

Great Britain Crossrail TBM Ellie has broken through into a cavern 40m beneath Stepney Green, in the East End of London. The breakthrough marks the structural completion of tunnels for Crossrail's north east spur, between Whitechapel and Pudding Mill Lane.

It has taken Ellie three months to complete the 2.7km journey.

In the coming weeks Ellie will be lifted out of the cavern and taken by road to Limmo Peninsula at Canning Town. From there she will be re-assembled ahead of recommencing tunnelling towards Victoria Dock Portal.

Andrew Wolstenholme, Crossrail's CEO, said: "Ellie has made a safe journey from the shadow of the Olympic stadium to our site at Stepney Green. Our tunnel teams deserve congratulations for an impressive feat of engineering. Construction of the new rail tunnels for Europe's largest infrastructure project is now over 80 per cent complete."





JICA may conduct Manila Metro studies

Philippines Japan has promised to conduct a more comprehensive study on the feasibility of building a subway system in Metro Manila, Philippines president Benigno S. Aquino III said on 24 June.

In his arrival statement after his one-day visit to Japan, Aquino said he thanked Japanese Prime Minister Shinzo Abe for the studies conducted by the Japan International Cooperation Agency (JICA) that aim to improve the transportation systems in Metro Manila and in nearby areas. Aquino's statement comes after the JICA released a transport infrastructure roadmap in early June for Metro Manila, Bulacan, Rizal, Cavite and Laguna, as requested by the National Economic Development Authority

The roadmap includes preliminary studies for a subway project in the said areas and for a new project on the Ninoy Aquino International Airport (NAIA).

"We will consider the possibility of further assistance for the Subway and New NAIA, for which we believe Japanese technologies can be utilised," JICA Philippines Chief Representative Noriaki Niwa said. The Department of Transportation and Communications (DOTC) unveiled last March major railway projects including the proposed PHP 135bn (USD 3bn) project to build an underground mass rail service between the Makati central business district and Pasay.

The project is a proposed 20km loop that would consist of 16km of tunnel and 4km of elevated railway especially in the reclaimed area in Pasay City. It would consist of 11 stations, including five underground, four interchanges and two elevated stations.

MRT study second phase begins in 2015

Indonesia Japan International Cooperation Agency (JICA) has provided IDR 150 to 200bn (USD 12.5M to 13.4M) for the second phase of the north-south corridor construction project feasibility study that will begin in 2015 after auction, PT MRT Jakarta president, Dono Boestami, said on 26 June. The initial study was conducted in 2010.

The second phase will expand the north-south line from Hotel Indonesia to Kampung Bandan (North Jakarta), with 8.1km of railway (seven underground stations and one ground-level station). Dono said this study would be done in one year, confidently believing the project would be finished on time. "Delay of one to two months is not a problem," Dono said.

Several private and foreign companies have expressed interest in funding the project, Dono added. There are three alternative schemes of the project funding: the state and regional budgets, loans from privates sectors and public private partnership (PPP). PT MRT is still reviewing the three schemes as each one has its strengths and weaknesses. According to Dono, the state and regional budgets can fund the project, but the budget needed, which is IDR 15 to 16tn (USD 1.25bn to 1.34bn), can still be used for other projects. Private loans need a long administration process while PPP has the possibility of disagreement between stakeholders.

Baku road tunnel to be operational by July

Azerbaijan OJSC Construction & Industrial Investment Corporation (Akkord) has completed construction of a closed part of a tunnel on Ziya Buniyadov Avenue in Baku, Azerbaijan Business Center (ABC) reported on 23 June. The company said that construction of the highway tunnel junction at the intersection of Ziya Buniyadov Avenue and Boyukshor Street began in March 2011.

"The work is carried out to order of Azeryolservis, a company of the Transport Ministry, Gidrotransproekt, is the tunnel designer and Akkord the project contractor. So far, work has been finished in the closed part of the tunnel to be commissioned in July," Akkord said in a statement. According to the company, the ongoing work concerns asphalt laying on roads running along the tunnel, with a total length of 1,600m, installation of lights inside the tunnel and nearby roads, construction of a roundabout above the closed section of the tunnel, as well as work on the reconstruction of a 140m road.

MAKKAH PLAN TO AVOID TUNNEL JAMS

Saudi Arabia Civil Defence authorities in Makkah are on a mission to combat the toxic air emissions that result from the increased influx of vehicles during the Muslim fasting month of Ramadan.

"The authorities are focusing on improving ventilation and controlling carbon emissions inside Makkah's tunnels during the holy month," said Colonel Saleh Al-Olyani, Makkah Civil Defense spokesman.

"In fact, authorities have deployed 12 teams to measure toxic air emissions inside 58 tunnels in the holy city around the clock."

Getting to and from Makkah's Grand Mosque during Ramadan is a challenge for pilgrims and authorities alike.The city's tunnels see a massive influx of cars and trucks, especially in the evening hours following the Ramadan "taraweeh" prayers, exacerbating already high pollution levels.

As such, controlling the rate of emissions inside these tunnels can prove challenging.

Only public transport vehicles are allowed into Makkah's tunnels during the holy month. Despite these measures, the harmful fumes emanating from diesel-operated engines pose a health threat to residents and pilgrims.

"The Civil Defence has adopted a comprehensive plan for the management of tunnels around the Grand Mosque, especially during the peak hours before and after evening and taraweeh prayers," he said.

"Teams will measure carbon emissions rates in order for traffic authorities to be able to streamline the flow of vehicles," he said.

"Authorities plan to prevent vehicle overcrowding."

Makkah's 58 tunnels span over 20km. The city's municipality recently signed a three-year maintenance contract for these tunnels worth almost SAR 11M (USD 2.93M).

The Souq Al-Sagheer tunnel connecting the Grand Mosque and Umm Al-Qura is considered the most pivotal in easing traffic in the central area.

The tunnel, which has separate lanes for vehicles and pedestrians heading to the mosque, contains 882 sodium lamps, 2,123 fluorescent lamps, 68 jet fans, eight escalators and eight devices for measuring carbon monoxide levels, according to the municipality.

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DIBA-LIMA-KHASAB ROAD AND TUNNEL CONSULTANCY TENDER FLOATED

Oman The Ministry of Transport and Communications on 23 June floated a tender to select a consultant for preparing tender documents for Diba-Lima-Khasab road and tunnel, which is on a design, build, operate and maintain basis.

The road is considered to be one of the strategic linking roads in Oman that will enhance trade and facilitate the flow of traffic between the wilayats (administrative divisions) of Musandam governorate and contribute to revitalise tourism in the governorate.

The consultancy tender was due to be opened by 15 July, while the documents were to be distributed up to 8 July.

Estimated to cost in the range of USD 1bn, the project is among the most complex roads to be undertaken in the Sultanate of Oman. A tender for selecting a project management consultant (PMC) was floated by the government recently.

A study for the 65km-long road, which will be developed on a twenty-year concession with a private operator, has already been completed and a tender for pre-qualification of companies was floated last year.

As many as 31 local and international companies are looking to pre-qualify for the construction work of the Diba-Lima-Khasab road project section two.

Chancellor unveils London's newest tunnel

Great Britain Chancellor George Osborne unveiled London's newest tunnel under the River Thames in early June, Crossrail announced. The Thames Tunnel, part of the GBP 14.8bn (USD 25.2bn) Crossrail project, stretches for almost two miles is planned to open in 2018.

The Chancellor was joined 15m below ground under the river Thames at North Woolwich by Crossrail Chairman Terry Morgan and Crossrail apprentices who have worked on the tunnels.

"As part of our long term economic plan we are investing in infrastructure around the country to create a more balanced, resilient economy," Osbourne said. "Crossrail is not only providing extra speed and capacity for London's passengers, but also supporting new housing, jobs and businesses."

Boris Johnson, mayor of London, said: "London is the engine room of the UK and projects such as Crossrail are helping to drive our country's economy in the right direction. Completion of The Thames Tunnel is yet another important chapter in the Crossrail story - a tale that perfectly highlights how investing in major transport schemes can trigger development and unlock the potential for thousands of new jobs and homes."

Since 2008 there have been planning applications within a kilometre of Woolwich Crossrail station for 4,286 new homes, over 70,000sqft (21,336sqm) of new office space and 114,000sqft (34,747sqm) of new retail space.

It is estimated by Crossrail that the infrastructure project will generate in excess of some 75,000 business opportunities and also support the equivalent of 55,000 full time jobs around the UK.

Jeddah transforming into a 'city of bridges and tunnels'

Saudi Arabia Jeddah will soon become a city connected by bridges and tunnels, Mohammed Al-Buqami, Jeddah Municipality spokesman, said on 27 May.

"The city is in the process of implementing several infrastructure projects to construct more new bridges and tunnels in various areas in order to smooth traffic flow," he said.

"Bids to implement these projects have been referred to giant domestic and international construction firms.

"There is a project currently being implemented between the King Abdulaziz Street and Ismail Abu Dawood intersection," he said. "We then have two important projects taking place between Prince Majid and Makkah streets and at the intersection between Palestine and Andalus streets

Al-Buqami said that the latest King Abdulaziz and Ismail Abu Dawood project would represent a significant new addition to the road and transport network in Jeddah.

"The newest project consists mainly of a one-way overpass with two lanes that are 740 meters long and more than nine meters wide on King Abdulaziz Street.

"The project also includes a two-way overpass that is 609m long and 26.4 meters wide with three lanes in each direction."

He noted that there is a 36-month timeframe to complete the project.

The second project, he said, includes building a tunnel on the intersection between King Abdulaziz Street with Palestine and Hamra streets.

This will involve implementing a north-south tunnel all the way along King Abdulaziz Street spanning 1,400m.

Underground passage mulled for Phom Penh

Cambodia The Overseas Cambodia Investment Corp. (OCIC) and Phnom Penh municipality are cooperating to undertake a study on new major projects for the city – two flyovers and a subway, each of which it is hoped would ease the city's ever worsening traffic congestion.

Touch Samnang, project manager at OCIC, said in Phom Penh on 1 May 2014 that his company and the municipal authorities are currently examining the feasibility of the two flyovers.

He said the first one would be at the intersection of Mao Tse-tung and Russian boulevards (close to the Institute of Technology of Cambodia) and the second would be at the intersection of Hanoi Road and Russian Boulevard.

Samnang said the subway under consideration would run from the intersection of Monivong and Russian Boulevard to Street 114.

The studies are still in the preliminary phases, and a blueprint has only been drafted for one of the flyovers so far.

What do you think? Send your views to the editor and join the debate

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Typical installation of the RST Profile Monitoring System for Tunnel Concrete Segments with an RST flexDAQ Datalogger System.

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TBM DUTY EXEMPTION YET TO BE REALISED

Pakistan The exemption of duty for TBMs and other important equipment – for the ongoing 969MW Neelum Jhelum Hydro Power Project (NJHPP), located in Azad Kashmir, 22km south of Muzaffarabad – was yet to be realised as *Tunnels* went to print despite the directives of Pakistan's Finance Minister Ishaq Dar.

The CEO of NJHPP Lt. Gen. (retired) Zubair, while talking to the official Associated Press of Pakistan (APP) news agency in Islamabad on 7 June, said that some necessary equipment has already been reached at Islamabad Airport and Karachi Port. However, the concerned department has not yet cleared it despite exemption. He said the finance ministry, on the directives of Prime Minister Nawaz Sharif, has approved PKR 14bn (USD 142M) for this purpose and expressed the hope that the equipment would be released soon.

Zubair said that overall 61 per cent work has been completed on the project and all out efforts are being made to complete it before its scheduled time (2016). He added that the project would cost PKR 274bn (USD 2.8bn).

Zubair expressed the hope that the first power unit of 242MW would start generation by December 2015 subject to availability of funds.

He said that 72 per cent work on the main dam has also been completed while work on a 19km tunnel.

Jim Crawford to join HS2 construction team

Great Britain HS2 has appointed Jim Crawford as programme director – Phase One. Crawford joins from Network Rail where he was the major director for the GBP 6.5bn (USD 10.9bn) Thameslink upgrade.

Simon Kirby, HS2 construction CEO, said: "Building Britain's much-needed high speed rail network will be a major undertaking and we need the best people to help deliver it on schedule and within the budget we have been set. Jim Crawford's experience speaks for itself but I know just how capable he is from our time together at Network Rail, working on the multi-billion pound investment in Thameslink.

"I am very pleased that someone of Jim's calibre is joining us as we have much to do between now and when we expect to have spades in the ground in 2017.

At High Speed Two, Crawford will be completing the set up of the team that will be responsible for the delivery of the multi-billion pound construction programme for the first phase of the new high speed rail network between London and West Midlands.

Tunneller to retire after 50 years in the business

Great Britain A tunneller currently working on Crossrail is set to retire after 50 years underground working on some of London's largest infrastructure projects. Peter Bermingham, 70, was to retire at the end of May.

Bermingham began his career 50 years ago in 1964 when he worked on the construction of the Victoria line from Green Park to Oxford Circus. Since then he has worked on more than 20 projects in and around London including the Jubilee line Extension, the Olympic Park and the King's Cross redevelopment.

"When I started out tunnelling back in 1964, I never thought that I'd still be doing it 50 years later," said Bermingham. "It's the camaraderie and the spirit among the lads that's kept me in the industry for so long and I'll miss it when I retire. Going under the Thames for the tenth time as part of Crossrail felt pretty special, in particular on a project that is going to have such a big impact on London.

"I've seen enormous changes. Back when I started out, we dug tunnels by hand using pneumatic spades and shovels, normally with a cloth cap or a handkerchief on our heads. Now we're using ten million pound machines to build the tunnels beneath the streets of the city."

Andrew Wolstenholme, Crossrail chief executive, said: "Peter should be rightly proud of the 50 years service that he has given to the tunnelling industry and to London. The wealth of experience that he has brought to Crossrail has been unparalleled and we all wish him the best for retirement."

Terratec lands Turkish and Laotian TBM orders

Turkey-Laos Manufacturer Terratec recently announced two new TBM sales. The machines are destined for the Istanbul Metro project in Turkey, and the Xe Namnoy hydropower project in Laos.

The first machine, a 6.56m-diameter EPB will bore the Mecidiyekoy to Mahmutbey (M7 Line) that will be 18km long and serve 15 stations when it enters service in 2017. Terratec said the design of the cutterhead is versatile to deal with the mixed geology expected on the project. The contractor is a joint venture of Gülermak, Kolin and Kalyon.

The second TBM is a 5.74m-diameter hard rock double shield machine, and will be utilised by tunnelling subcontractor Seli Overseas to bore an 11.5km headrace tunnel and install hexagonal concrete segments. Geology will primarily consist of the siltstones, sandstones and conglomerates of the Champa Formation, and the mudstones and siltstones of the Tholam Formation. The project is being developed by main contractor SK Engineering and Construction.

Bekaert and Maccaferri announce partnership

Belgium-Italy Bekaert and Maccaferri announced a 50/50 partnership for global sales and distribution. The remit of the joint venture will be to provide complete construction reinforcement solutions for underground infrastructure projects.

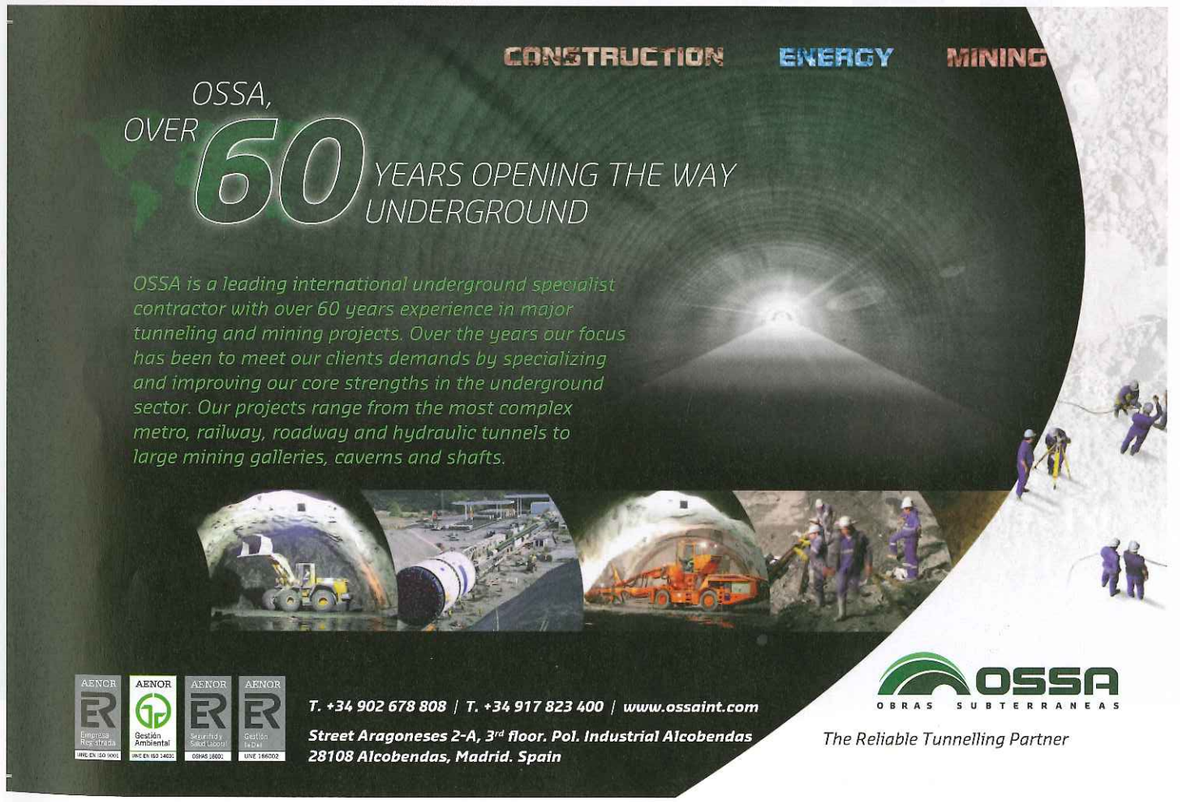
A spokesman for the companies explained "[The partnership] will combine the sales and distribution of Bekaert's Dramix steel fibers for the reinforcement of concrete in underground construction projects such as shotcrete and precast applications, with Maccaferri's complementary underground solutions, such as steel arches, concrete chemicals and glass fiber soil consolidation elements.

The joint venture will be serving underground construction markets on a worldwide basis, except in mainland China and Hong Kong, Argentina, Brazil, Paraguay, Peru, and Uruguay, where Bekaert and Maccaferri will continue to operate independently.

The establishment of the joint venture is subject to customary closing conditions.

Belgium's Bekaert is a world market and technology leader in steel wire transformation and coatings. Italy-based Maccaferri offers engineered solutions from reinforced soil structures, road stabilisation and natural hazard mitigation to hydraulic, and landfill work.





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THE SEATTLE SAGA

After six months of tunnelling standstill, construction is starting on an access shaft to repair the TBM mining the SR 99 bore in Seattle, the largest diameter machine in the world. **Nicole Robinson** explores the machine's initial journey and downtime



Nicole Robinson
Managing editor of *Tunnels North America*
Nicole is based in Minneapolis, Minnesota

LAST AUTUMN, the world's largest diameter TBM was making significant progress mining below Seattle. It was quite possibly a mere week away from installing the 200th ring, marking the final manufacturer's hand-off, in December when tunnelling stopped, and has yet to properly resume.

March 2015 is the most recent deadline for the TBM to start mining again. Stalled underground for six months, by the time this issue goes to print, there are still many questions about damage to the machine, repair work and the cost in both time and dollars to the project.

Japan's Hitachi Zosen is supplying the EPB TBM, 57ft (17.5m) in diameter, that will build the world's largest diameter deep bore, a highway tunnel accommodating four lanes of traffic in a double-decker formation.

The tunnel is 1.7 miles (2.7km) long and reaches a depth of 120ft (36.5m) from sea level, while maximum cover is 215ft (65.5m). The maximum horizontal curve is 2,000ft (650m) and the maximum vertical gradient is 4 per cent.

The Washington State Department of Transportation (WSDOT) is building the tunnel to replace the Alaskan Way Viaduct, which sustained damage after a 2001 earthquake and was deemed



Below: Crew members adjust the segment feeder. WSDOT



unlikely to survive another one.

WSDOT awarded a design-build contract worth USD 1.35bn to Seattle Tunnel Partners (STP), a joint venture of Dragados USA and Tutor Perini. The agency said in January, "we were drawn to one component of their proposal, which involved building a protected underground area along the first 1,500ft (460m) of the tunnel drive.

"In addition to protecting the viaduct and other structures in this very shallow, challenging section of the route, this protected area allows the contractor to test all functions of the tunnellng machine and its operations prior to tunnelling under downtown Seattle."

STP launched the TBM at the southern portal on July 30, 2013. The alignment descends at four per cent gradient to attain maximum depth prior to the TBM passing beneath the existing viaduct foundations, approximately 1,750ft (533m) after the launch site.

Above: The tunnel alignment and the TBM's location

Below: A surveyor sets up his gear near the south end of the SR 99 tunnel on Friday, December 6, 2013

STANDSTILL

On Saturday, December 7, 2013, STP stopped tunnelling "after unanticipated and increasing resistance was experienced, possibly due to an obstruction, which significantly decreased the advancement rate of the machine and the volume of tunnel muck on the machine's conveyor belt," WSDOT would announce the next week.

About 60ft (18.3m) underground, the TBM had mined more than 1,000ft (305m) but was still in the section of the tunnel drive with difficult ground due to the historic fill soils. Shallow depth and the high groundwater table also had to be factored into any decisions for moving forward on the drive.

158
The hours of inspection work carried out by the teams, removing dirt and other material



STP attempted to identify and remove any potential obstructions by installing wells approximately 120ft (36.6m) deep near the TBM to lower water pressure in the ground, allowing workers to enter the excavation chamber at the front of the machine. At the same time crews drilled 17 exploratory probes in front of the machine to look for objects that might be blocking the TBM's path, encountering obstructions in four of the probes.

Over the month of December more than 300,000 gallons of water were removed and on Wednesday, December 20, crews were able to turn the machine's screw conveyor and remove some muck from the excavation chamber. "As the muck lowered, a crew member was able to take a quick peek through a hatch near the top of the machine. What they saw inside was dirt, sand and cobbles – nothing extraordinary. Because water quickly filled the part of the chamber that was previously occupied by muck, they were only able to look around for a few minutes before they had to close the hatch," according to information released by WSDOT.

CASING CONCERNS

On January 2, crews successfully reduced water pressure enough to inspect the top 15ft (4.6m) of the excavation chamber. A piece of an 8in (203.2mm) diameter steel pipe could be seen protruding through an opening in the machine's cutterhead. Probes from the surface also detected metal in front of the machine.

The steel pipe is a well casing installed in 2002, after the 2001 earthquake, to help geologists better understand how groundwater moves in the area. The location of this pipe was included in reference materials in the contract, WSDOT says.

Once the face was accessible STP crews carried out maintenance, inspecting and replacing damaged cutter tools on the face of the machine while further investigation work continued.

On January 5, Malcolm Drilling, as a subcontractor to STP, started drilling four, 5ft- (1.5m-) diameter shafts in front of the TBM where earlier probing detected metal.

It was hoped the shafts would further identify the limits of any metal in front of the machine and remove as much



of it as possible. However, if no objects were detected or removed from the shafts, they would be filled to form part of an underground barrier that would create a safe environment for workers to enter the machine's excavation chamber.

Drilling to a depth of approximately 118ft (36m) starting on January 7, investigations in the first three shafts produced inconclusive results. By January 13 the third shaft was being refilled, and drilling for the fourth was put on hold.

Above: The crew discusses progress in November 2013.

Below: Locations of exploratory shafts this winter

HYPERBARIC INTERVENTION

On January 17, crews entered the excavation chamber to inspect the cutterhead under hyperbaric conditions. Within the first 35 hours, they cleaned the spokes and removed a bent piece of metal well casing and plastic PVC pipe and identified a large boulder or piece of concrete material in a cutterhead opening.

"We changed a significant number of tools going in through the spokes. When we did the hyperbaric interventions we changed more cutting tools on the cutterhead," Dixon would later explain in a press briefing on February 11.

Hyperbaric intervention finished on Tuesday, January 28, with crews performing 158 hours of inspection work, including removing clogs of dirt and other material in the cutterhead openings, and replacing cutting tools. No major obstructions were found inside or in front of the machine.

That same day, after the hyperbaric work completed, STP moved the TBM forward by about 2ft (0.61m) to build the next tunnel lining ring (ring number 150), which was in progress before the machine was stopped on December 6, followed by an evaluation of the machine and its operating systems.

When the machine moved forward, crews saw indications of above-normal temperature readings in part of the machinery, similar to readings encountered before crews initially decided to stop mining on December 6. The next day, Wednesday, STP made adjustments and mined an additional 2ft (0.61m). The above-normal temperatures persisted, and STP made the decision to stop and continue investigations, which would then reveal damage to the seal system protecting the TBM's main bearing.

"Portions of the seal system have been damaged and need to be repaired or replaced," WSDOT announced on February 7. "STP and its tunnelling experts are working with the machine's manufacturer to determine the best fix for this issue."

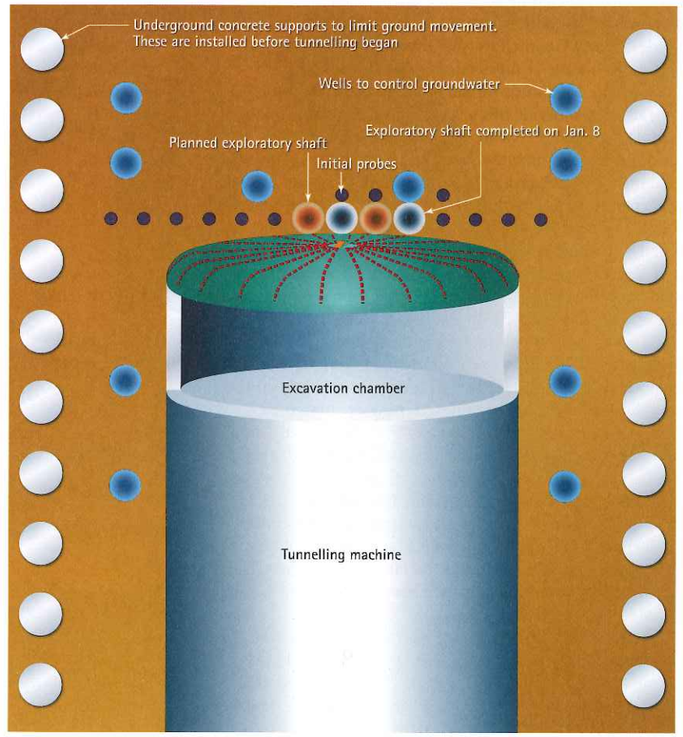
Tunnels and Tunnelling contacted both STP and WSDOT for this article to discuss the investigation and potential causes for the machine's damage. STP responded via WSDOT that it is still actively investigating the root cause of the machine's issues and could not answer questions about the investigation work or potential causes of the damage at the time of the magazine going to print.

REPAIR PLANS

Todd Trepanier, WSDOT's administrator for the Alaskan Way Viaduct Replacement Program, and Chris Dixon, project manager for STP spoke with reporters about the TBM Tuesday, February 11.

At the same time Hitachi Zosen staff flew in from Japan to help develop repair plans and assess the situation. STP considered two options—digging an access shaft in front of the stalled machine or accessing the machine from the back, performing repair work under hyperbaric conditions.

On February 21, STP announced it had decided to access the seal system through the front of the machine by digging a vertical shaft 100ft-deep by 80ft-wide (30.5m by 24m) shaft in front of the TBM, driving the machine forward into the shaft and then making the needed repairs. Dixon initially estimated



that this work will take at least six months.

Two months later, STP released more information about the repairs and confirmed the TBM won't start up again until March 2015. At the time of publication, STP confirmed it will replace the machine's main bearing and install a more robust seal system, "which could include strengthening the seals, installing redundant systems, and adding monitoring equipment." Additional details will be included in a plan to be submitted to WSDOT for review by June 16.

WSDOT's contract with STP mandated an extra bearing be manufactured for the project.

"We are disappointed by this delay, but we believe the new schedule is moving in the right direction," Trepanier said. He adds, "We're also focused on the rest of the program, which includes more than USD 750M worth of work at the tunnel portals and elsewhere along the SR 99 corridor. That construction is not affected by the tunnelling stoppage and continues full speed ahead."

By September the shaft should be fully excavated and repair work on the seal system and main bearing is expected to start by October. Testing for the machine is scheduled for February 2015. "Resuming tunnelling will take longer than any of us would have liked, but making these repairs is a significant engineering challenge that must be done safely," said Dixon on April 21. "We are committed to this project, and to taking the necessary steps to recover time and open the tunnel to drivers by WSDOT's original target date."

RECOVERING TIME

WSDOT's expert review panel (ERP) for the project released its 2014 report on February 27. It states: "the TBM position on December 6 when it stopped was within two feet of its originally scheduled location. This indicates significantly better than expected performance of the TBM while it was mining." The ERP is chaired by Patricia Galloway, and includes Robert Goodfellow and John Rose.

In the February 11 press briefing Dixon explains, STP planned on a 14-month tunnel drive, starting in July 2013 going to September of this year. Its original construction schedule included 339 working days to mine the tunnel, including time for maintenance and interventions. This was based on a planned production rate that was slower at first, but increased to nearly 40ft (12m) per day – a pace that STP believes is conservative when the machine is functioning properly. "We planned the work on a five-day per week, two-shifts per day, 10-hours per shift, he said. "If we went to a 7-24 that'd be 168 hours a week so that'd be a 68 per cent increase in the available work hours per week.

"When you go to an around the clock operation you're not quite as efficient, so each hour you're working over the 100 hours you're not necessarily picking up an hour on the schedule but you have the ability to recover some time."

He also points out that originally STP planned to start tunnel interior structures, electrical and mechanical and other systems work once the TBM had mined 2,000ft (610m). And that there was also downtime planned in safe haven three (the last stop before mining below the actual viaduct foundations and deeper underground) for work in the launch pit, some of which can be performed during the current downtime, which will shorten the time spent in safe haven three when the TBM ultimately gets there.

"The fact that the machine performed very well in its initial tunnelling...achieved the same footage in the first 135 days that we planned even though we were stopped for a month with the Longshoremen picket line. So the machine performed and advanced much faster than we were anticipating."





Above: Drilling in front of the TBM in January

Above: Part of the steel pipe and other items encountered by the TBM

The newly announced timeline delays tunnel boring by up to 16 months, however STP hopes to recover as much as four months of schedule to meet WSDOT's original tunnel opening date of November 2016. STP had proposed a contract completion date for December 31, 2015.

CAUSE OF THE CLOG

WSDOT says it does not believe that the well casing was a major contributor to the current stoppage.

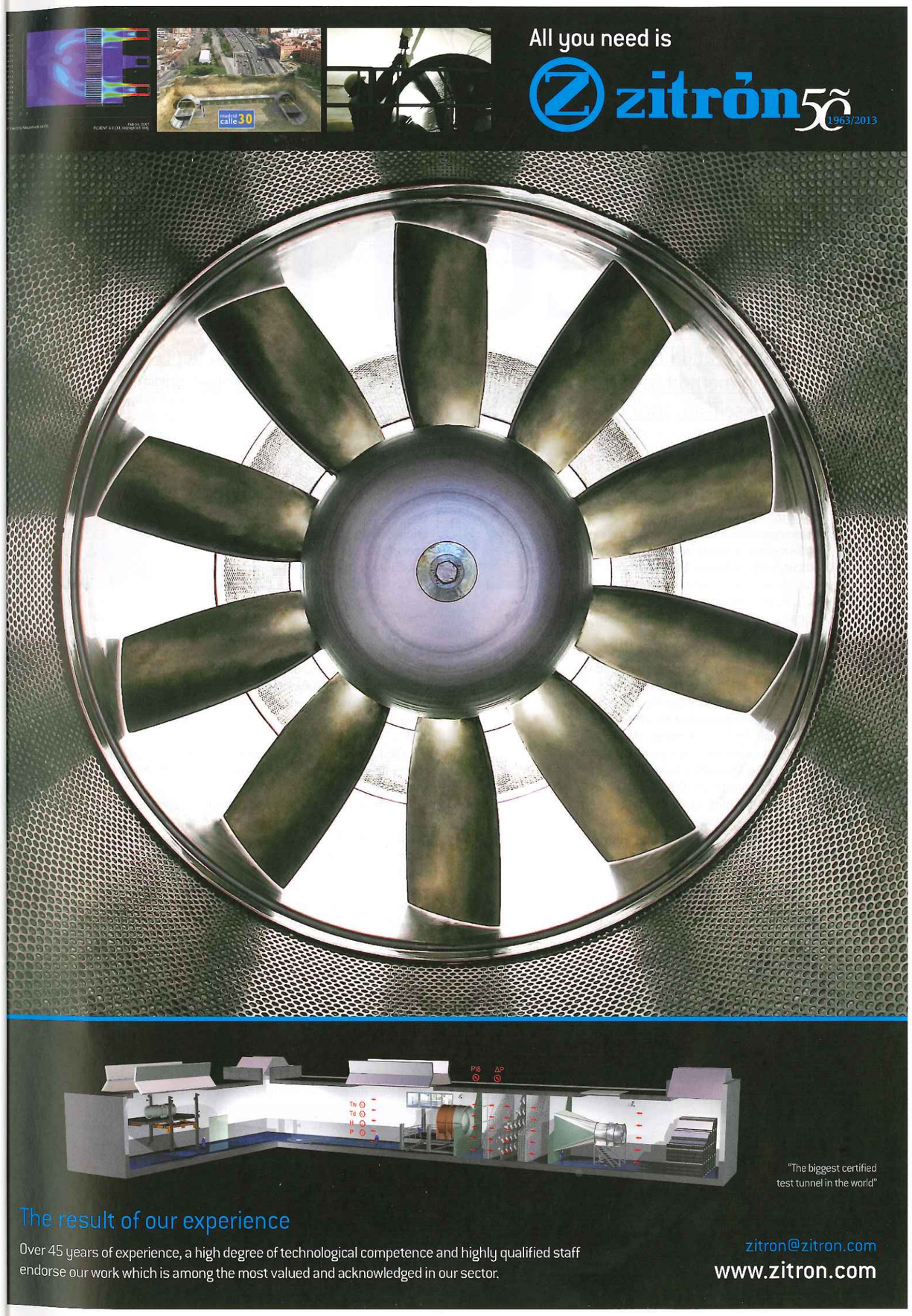
In the February 11 press briefing Dixon says there are a variety of reasons that the seals could have been compromised, but STP will not be speculating. "We believe that there was pretty significant damage to the cutting tools," Dixon says.

He adds, "We believe the cutting tools were damaged by the pipe."

In reference to the well-casing pipe causing damage to the cutterhead, he later says, "We think that created friction, which created heat, which could have resulted in damage to the seals.

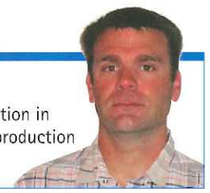
"But again it's something we have to prove to WSDOT. Tight now it's just a theory that we have. All I'm really saying is we haven't ruled out the pipe as a contributing factor.

"How it contributed, we're still looking at that. That's just one of the theories we have as to how it could have contributed to the problem"



FORMING A SOLUTION

Ben Roberds and **Eric Gemin** of *Redpath* describe the top heading and bench excavation method for the Waneta Expansion Project, and the challenges and benefits of using a self-advancing tunnel form on a 17 per cent slope



Ben Roberds
Ben started with J.S. Redpath Corporation in 2005 working in safety, engineering, production and currently as Project Manager.



Eric Gemin
Eric works for J.S. Redpath Corporation and has been in the tunneling and underground industry for eight years on a half a dozen projects.

THE WANETA Expansion Project (WAX) is located near the existing Waneta Dam site at the confluence of the Pend d'Oreille and Columbia Rivers approximately 10km south of Trail, British Columbia. The WAX owners consist of a partnership between Fortis, Columbia Basin Trust and the Columbia Power Corporation. This design-build project was awarded to an Aecon/SNC Lavalin joint venture (ASL-JV) in late 2010 and is expected to be in operation mid 2015.

The WAX consists of a new 335MW powerhouse including two new Francis turbine units, each generating approximately 167MW. The powerhouse is located downstream of the existing Waneta Dam and will make use of excess water that would otherwise be spilled during the runoff season. Water will be funnelled to the turbines through an intake structure and two 10.5m diameter, concrete lined penstock tunnels. A 10km transmission line will connect the powerhouse to existing electrical grids.



Below: Work on the penstock tunnels. All photos courtesy of Columbia Power

A joint venture of J.S. Redpath Limited, and Frontier-Kemper Constructors ULC, Waneta Tunnelers (RFK), was subcontracted by the heavy civil contractor ASL-JV, to excavate the tunnels and install the cast in place concrete liner.

ACCESS ADIT

To start the penstock tunnel excavation early, while powerhouse and intake excavations were underway, a smaller access adit tunnel was developed. The access adit was 6m wide by 6m tall, modified horseshoe in shape, and 135m long with a grade of -12 per cent. Developing the access adit allowed RFK to excavate the penstock tunnels and remain off of the surface works critical path and out of the way of other site excavations. The access adit was also used for initial training for those workers not familiar with underground excavations (Figure 1).

Four meter round lengths were drilled using a 2-boom Tamrock drill jumbo. A typical round consisted of 75 holes, 45mm in diameter with three 100mm diameter relief holes in the cut. Hole spacing was approximately 800mm by 800mm. Explosives used were packaged emulsion, "stick powder", with Nonel detonators. All blasts were initiated using electric blasting caps which were tied into detonating cord. Ground support in the access adit consisted of a minimum 50mm layer of 35MPa, fiber reinforced, shotcrete followed by a typical 2m by 2m pattern of 2.4m long expandable (Swellex) type rock bolts. The access adit had low cover and would be used as primary ingress/egress during the tunnel excavation and the concrete liner phase. Eight steel arch sets were therefore installed at the portal on one meter centers to provide additional ground support. All utilities and ventilation were routed through the steel sets and down the access adit. RFK was able to complete the 135m-long access adit in 40 days, working five days per week with two 10-hour shifts per day.

PENSTOCK TUNNEL EXCAVATION

Two penstock tunnels were designed parallel, 10m apart, horseshoe in shape, and approximately 11m in diameter. After excavation a 300mm thick cast in place concrete liner would be installed for hydraulic efficiency purposes only. Due to the large diameter of the penstock tunnels RFK determined the safest and most efficient excavation method would be top heading and bottom bench. Separating the excavation into top and bottom halves allowed RFK to keep tight control over ground support and minimise the amount of open ground at any time. Another deciding factor was the availability of smaller mobile equipment.

Based on the tunnel size and expected ground conditions initial planning suggested further dividing the excavation through the use of a split top heading method. In this scenario the top heading in each penstock tunnel would have two separate working faces side by side, one slightly ahead of the other, each approximately 5m wide by 5m tall. This method, similar to a pilot and slash, would have provided four working faces at any given time yielding greater flexibility in the excavation cycle.

As access adit excavation neared the intersection of the penstock tunnels RFK encountered better than expected ground conditions and determined that a full width top heading could be taken without compromising safety during the ground support cycle. Based on this information RFK chose to take a full face top heading, 11m wide by 5m tall, semicircular in shape. Doing so eliminated the flexibility of four separate working faces but allowed RFK to advance the entire top heading with one blast instead of two, making the operation more efficient overall.

Conversely, sequencing the excavation cycles between the four working faces would have required careful day to day planning and left little room for errors such as equipment breakdowns. Bottom bench excavation was always planned as full face using horizontal drilling and taken after top heading excavations were completed in each tunnel.

Controlled blasting techniques were employed during top heading excavations to help define the excavation line and minimise overbreak in efforts to reduce the amount of concrete placed during the tunnel lining phase. Top heading drill patterns had approximately 98 blast holes with interior spacing averaging 800 by 800mm. The perimeter of each round was line drilled with spacing averaging 450mm and every other hole loaded during the blast. Four meter round lengths were drilled using the Tamrock 2-boom jumbo. Mucking was done using two CAT Elphinstone R1700G Load Haul Dump (LHD) scoops. Due to the wide top heading, 11m, RFK was able to use both LHDs to muck the face simultaneously, passing in the tunnel near the face. The use of two LHDs at once helped decrease the mucking cycle.

135
Metre-long access adit was excavated in 40 days

300
The depth in millimetres of the cast in place concrete liner

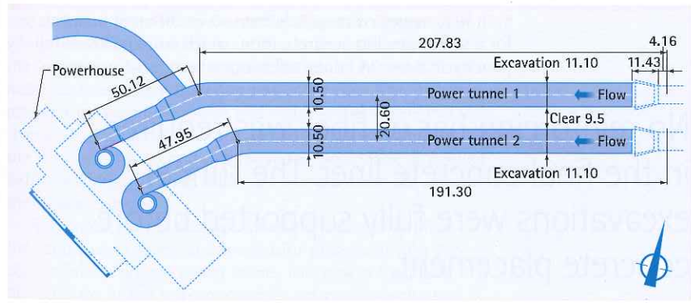
98
Blast holes, approximately, in the top heading drill pattern

From the access adit intersection power tunnel excavation was uphill at approximately 17 per cent for 190m and downhill at approximately -15 per cent for 20m in both tunnels. Blasted rock was taken to the downhill side of one power tunnel which was used as a muck bay. The downhill side of the adjacent tunnel was used as a sump. Blasted rock was hauled to surface from the muck bay after the heading was completely mucked out.

Initial temporary ground support, identical to that installed in the access adit, was installed in the penstock tunnels to allow RFK to continually advance the heading. All shotcrete was placed using a Normet Spraymec robotic shotcrete machine. Shotcrete was transported from surface using a single, 7 cubic meter, underground remix truck. Permanent ground support, consisting of 22mm diameter by 4m long, fully grouted rebar dowels were installed non-critical path behind the working face. All permanent ground support was installed based on a prescription by the onsite geotechnical engineer. Five separate rock classifications were defined and evaluations carried out daily after each blast was taken.

Ground support classifications ranged from Class I, spot dowels only, to Class V, 100mm of fiber reinforced shotcrete and lattice girders. Ground conditions in the penstock tunnels were good enough that RFK was only required to install Class I and Class II ground support.

To ventilate the underground excavations RFK used a fully reversible suction system. Two 1.3m-diameter, 200hp ventilation fans were located on surface adjacent to the portal entrance. Two separate steel ducts of the same diameter were connected to the fans and advanced through the access adit. Once at the access adit/penstock tunnel intersection, one steel duct would split off to each tunnel. The steel ventilation duct always remained approximately 18m away from the working face in the penstock tunnels while a smaller 30hp, 0.9m diameter booster fan was used to push fresh air directly toward the working face. The 30hp booster fans were set up in each tunnel in a fixed location and used 0.9m flexible ducting, advanced with the heading. Average air flows in the penstock tunnels were approximately 5,500cu.m per minute.



Below: Figure 1, the twin penstock tunnels

Other utilities such as compressed air and service water were carried in 100mm diameter HDPE pipe hung along the walls of each tunnel.

Electrical cables for tunnel lighting and equipment were carried on the opposite side of the tunnel as the compressed air and water lines.

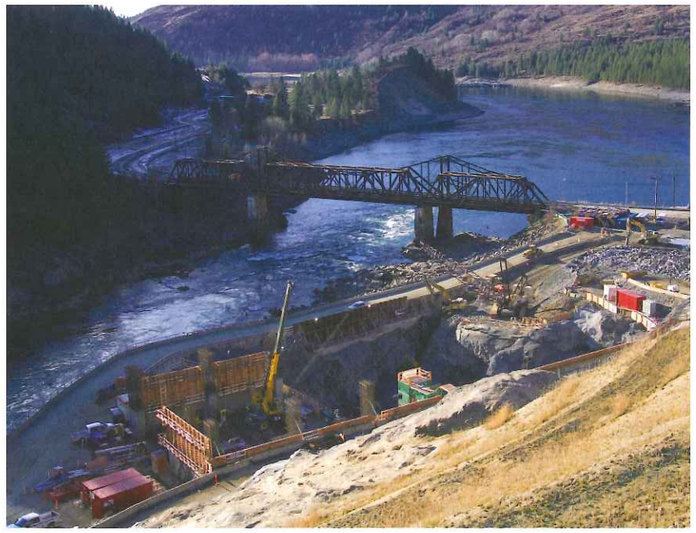
RFK was able to excavate both top headings, 451 linear meters total, in 139 days and completed the bottom benches in only 82 days.

Two disadvantages associated with the steep grade excavations were difficulty mucking uphill and increased exposure during ground support operations. RFK was able to mitigate the latter by using a remote shotcrete arm on the Normet Spraymec allowing an initial layer of shotcrete to be installed prior to bolting. Shotcrete accelerator was used to reduce cure times so that bolts could be installed during the same shift. A mechanised bolting machine was used to install the expandable bolts, again minimising exposure to the operators. Excavating and mucking uphill was technically more difficult for operators but the chosen equipment was designed for underground mines where steep grades are more common. The slope was hard on tires, but with careful operation standard equipment was used effectively without requiring modification.

One advantage of the steep grade was that a dewatering pump was not required during ground support, drilling, and loading cycles to keep the face dry.

CONCRETE LINER

A smooth concrete liner was specified to minimise head losses through the penstock tunnels. Initial plans were for a modified horseshoe, or D-shaped, tunnel cross section with finished inside dimensions of 10m x 10m. Prior to the start of excavation a change order was approved converting the finished tunnel shape to full round 10.5m finished diameter. With permanent ground support being installed during the excavation phase the liners would not be exposed to any ground loads. The maximum design load was thus the pressure differential caused by rapid dewatering. While the tunnels are in use, and full of water, the ground around them will become saturated with an equal hydrostatic pressure. In an emergency the intake gates could be closed and water would drain out of the tunnels in approximately two minutes. In this case of rapid dewatering the surrounding ground will maintain the full hydraulic head of up to 70m on the concrete liner until the pressure slowly dissipates through leakage. With this in mind the designers specified the use of 35MPa plain concrete to cast the 300mm thick liner.



Above: The Waneta work site and tunnel portal

It is notable that no reinforcing bar or fiber was required in the final concrete liner. The tunnel excavations were fully supported before concrete placement, and in the circular shape plain concrete was able to meet the design requirements. Reinforcement could have been used to reduce shrinkage cracking of the liner, but minor cracking was actually preferred as it will allow drainage into the tunnel during a rapid dewatering condition. Construction joints similarly required no water stop or bonding agents which would hinder equalisation of water pressures.

The design requirements did have restrictive finish specifications. The tunnel liner could not vary from line or grade by more than 12mm or by dimension/shape by more than 0.5 per cent. On the 10.5m diameter finished tunnel up to 52mm of differential between the height and width were allowed. Liner finish quality had to meet the British Columbia Ministry of Transportation Class II requirements. This required all honeycombs over 25mm diameter be filled, all bug holes over 5mm diameter be pointed and the surface given a rubbed finish where more than 50 such voids occurred per square meter. Surface irregularities 3mm high were allowed with restrictions on their size and number.

TUNNEL FORM DESIGN AND FABRICATION

To keep tunnel concrete works off the overall project's critical path RFK requested proposals from seven different suppliers for a self advancing concrete form, which would allow a full pour cycle every 24 hours, safely operate on a 17 per cent slope, and be able to meet the specified finish requirements. Ceresola Tunnel Lining Systems (CTLS) of Switzerland (now Max Bögl Schweiz) was the chosen supplier and undertook the design and fabrication of a walking beam style steel form. It was agreed the form would be able to cast a 7.5m-long full round section of the liner, walk itself through the tunnel on its own carrier, and be designed to operate on a 17 per cent slope. The form used by RFK on this project was the largest full round form CTLS had constructed to date.

> No reinforcing bar or fiber was required in the final concrete liner. The tunnel excavations were fully supported before concrete placement.

Since the tunnel form was only 7.5m long internal supports "spud pins" were not required. To prevent movement during concrete placement the front of the form was braced against the surrounding rock and the rear against the previous concrete pour by six large screw jacks on each end. Two screw jacks in the crown, one on each side, and two in the invert.

In an effort to reduce cycle times a steel framed, cantilever bulkhead system was developed which would fasten to the upstream leading edge of the steel formwork, eliminating the need to brace the bulkhead against the rock. In surface trials the provided cantilever bulkhead system proved difficult to fit around other installations on the end of the form such as walkways and hydraulic cylinders. The individual parts were also too heavy to efficiently assemble by hand on a regular basis. RFK decided to use rough cut 2x8 bulkhead material and support it using traditional wood 2x4 walers and stiff-backs. The wood supports were not designed to withstand concrete loads in cantilever so they were pinned and braced to the perimeter rock using 20mm steel dowels.

Advancement was accomplished by designing the round form and the carrier to walk itself. Rollers were installed on the carrier beams to allow the form to slide back and forth with the carrier resting on the ground. The same rollers could be used to move the carrier when supported by the form. Not having wheels on the ground meant the form could be walked over mildly uneven surfaces, did not require a rail system, and was stable in the sloped tunnel. The form could also be shifted sideways by means of small cylinders in the feet of the carrier.

The tunnel form was fabricated and structural elements assembled for testing and inspection in Seveso, Italy. After workshop inspection the form was disassembled and loaded into 11 standard 40ft (12m) shipping containers for transport to Trail, British Columbia. On arrival the 15 full form elements (1.5m x 7.5m x 1.6m up to 4,200kg each), 10 half elements for the invert, handrails and miscellaneous parts were skidded out of the shipping containers at a storage yard approximately 7km from the project site. Each element was then individually transported to the assembly location at the project site.

TUNNEL FORM ASSEMBLY

On site the assembly location was on the surface near the head pond and adjacent to the 40m deep intake excavation. The carrier itself was assembled then five elements comprising the crown were bolted together. The crown was lifted as one unit and attached to the carrier. The side elements, or wings, were bolted together and hung from the crown while the invert was assembled in place under the carrier. After the major elements were bolted together the electrical, hydraulic, pneumatic, communications and water systems were installed. Overall, surface assembly took 11 weeks. Once assembled, the form was tested and modifications were made as needed before walking the form under its own power to the edge of the intake excavation.

A location for the shortest lift crane radius (15m) into the intake was cleared and leveled for placement of a 275 US ton lattice boom crawler crane. This gave a load limit of 48,000kg at the self-imposed 75 per cent capacity to avoid the restrictions of a Critical Lift. Fully assembled the form weighed approximately 135,000kg.

The form elements, concrete placer car, and feet were removed to allow the carrier to be lifted and set in the bottom of the intake excavation. The invert, carrier, crown and sides, each containing all installed utilities and sub-assemblies, were then hoisted to the bottom of the intake, in order. Each part was directly attached to the elements already in place, reattaching the invert last.

After full reassembly the form was shifted 20m sideways using 200mm side adjustment cylinders and aligned with Tunnel 2. The form was then walked, as intended, to the downstream starting station of Tunnel 2 over the course of approximately one week. Although designed for the slope, a large moment was inflicted on the system as it was walked down the tunnel. When the carrier was raised and extended forward down the tunnel two screw jack feet on the lower end supported the majority of the system's weight; along with a moment from the extended carrier. An anchor pin assembly was provided on the upper end of the form to arrest longitudinal forces, but it was difficult to prevent load transfer to the vertical supports. Extreme care was required while walking downhill to prevent damage to the screw jacks. Advancing the form back up the tunnel did not have the same challenges. The carrier was advanced and set in place while the form was still enclosed in the previous pour's concrete. The tight encasement prevented any movement with loads being distributed into the concrete.

Adjustments had to be made after the first two pours to account for the rear of the form and carrier advancing into the poured liner. After the third pour a cycle was defined, although not close to the 24 hour target. A cycle consisted of fixing the form in place, building the bulkhead, pouring concrete, curing the concrete, striping the bulkhead, advancing the carrier, advancing the form, cleaning, oiling, and aligning the form for the next pour. After 10 pours the overall cycle was typically 48 hours (four shifts). Of the 48 hour cycle, concrete placement took only seven hours. The following shift stripped the bulkhead and moved the carrier forward. On the second day the form was advanced and reset. Night shift then started a new bulkhead and set up for the next pour. By the 15th pour the cycle had been reduced to 36 hours.

Several concrete mixes were submitted for approval to allow



flexibility based on weather conditions and temperatures. Because placement happened during the spring and summer months a mix design with the highest water/cement ratio (0.42) and highest fly ash content (22 per cent) was used. RFK determined this mix could be accelerated as needed to keep up with the pour schedule. Tight controls were necessary to ensure the concrete would perform as designed. Stripping strength of 4 MPa had to be reachable within 12 hours. Accelerator (typically 181ml/100kg cementitious) was added on site no more than 30 minutes prior to start of discharge. A minimum 180mm slump was needed because of the limited access behind the form to place and vibrate. At 220mm slump the concrete mix was too wet and began to segregate. The steep grade and use of high slump concrete helped to ensure all surface irregularities from the blasted rock were filled.

A Maturity Meter was used to monitor temperature production and rate of hydration of the placed concrete to allow stripping as soon as the concrete reached strength. Trial batches defined the rate of compressive strength gain to the Time Temperature Factor (TTF) output of the meter. When the TTF read 350 the bulkhead could be safely stripped (2MPa), as soon as it read 450 (4MPa) the concrete was self-supporting and the steel form could be advanced.

Above: The travelling form in the tunnel

RESULTS

Design of the tunnel form was based on the goal of placing one section of the tunnel liner every 24 hours on a schedule of three shifts/day eight hours/shift. Actual durations resulted in an average of one placement every two days on the first tunnel (25 pours in 49 work days) and one placement every 1.5 days (23 pours in 37 work days) in the second tunnel. Actual production was based on two shifts working 7:00am to 5:00pm and 6:00pm to 4:00am. Timing of the shifts allowed for a hot change from day to evening shift when required, but hot changes were not possible from evening to day shift. Pours that could not be started by the beginning of night shift were pushed back to the start of the next day shift.

Throughout both tunnels the pumping time averaged a stable seven hours, the variables of the cycle were the time spent curing, breaking down, moving forward and resetting the form. After initial start-up kinks were worked out the first tunnel typically required a minimum of two full shifts to move and set up the form.

If a pour started on Monday morning, the form could be set up to pour again Tuesday evening. Difficulties in securing concrete for evening pours, necessary conservative scheduling of start times, shift limitations and the learning curve extended the average cycle to a full two days. In the second tunnel, experience led to faster cycle times and tighter scheduling allowing pours as often as every 26 hours. Shift and material availability limitations as well as the continued learning curve pushed the average cycle to 36 hours.

An unexpected challenge of the concrete liner was excessive bug hole formation which required extra work to meet the finish requirement. In common concrete work a flat slab is placed with no upper form allowing entrapped air bubbles to escape into free air at the surface. A troweled finish would meet the finish specification with little or no follow up work. Vertical walls are vibrated in place allowing air bubbles to escape out the top of the pour, typically leaving only a small number of bug holes in the vertical surface depending on the concrete mix and placement practices.

The exposed face of a vertical wall should require limited effort to fill bug holes and patch rock pockets in order to meet a Class II finish.

The concrete placed below spring line in this project was cast against the broad surface of the form. The shallow curve of the large radius did not allow air bubbles to slide along the steel and escape into free air. The number of bug holes experienced required a rubbed finish to be installed below spring line in the whole of both tunnels. A stiff sand and cement grout was troweled over the concrete, allowed to take initial set and "rubbed" to create a uniform flat surface. The number of man hours spent finishing the concrete were comparable to the number spent placing it.

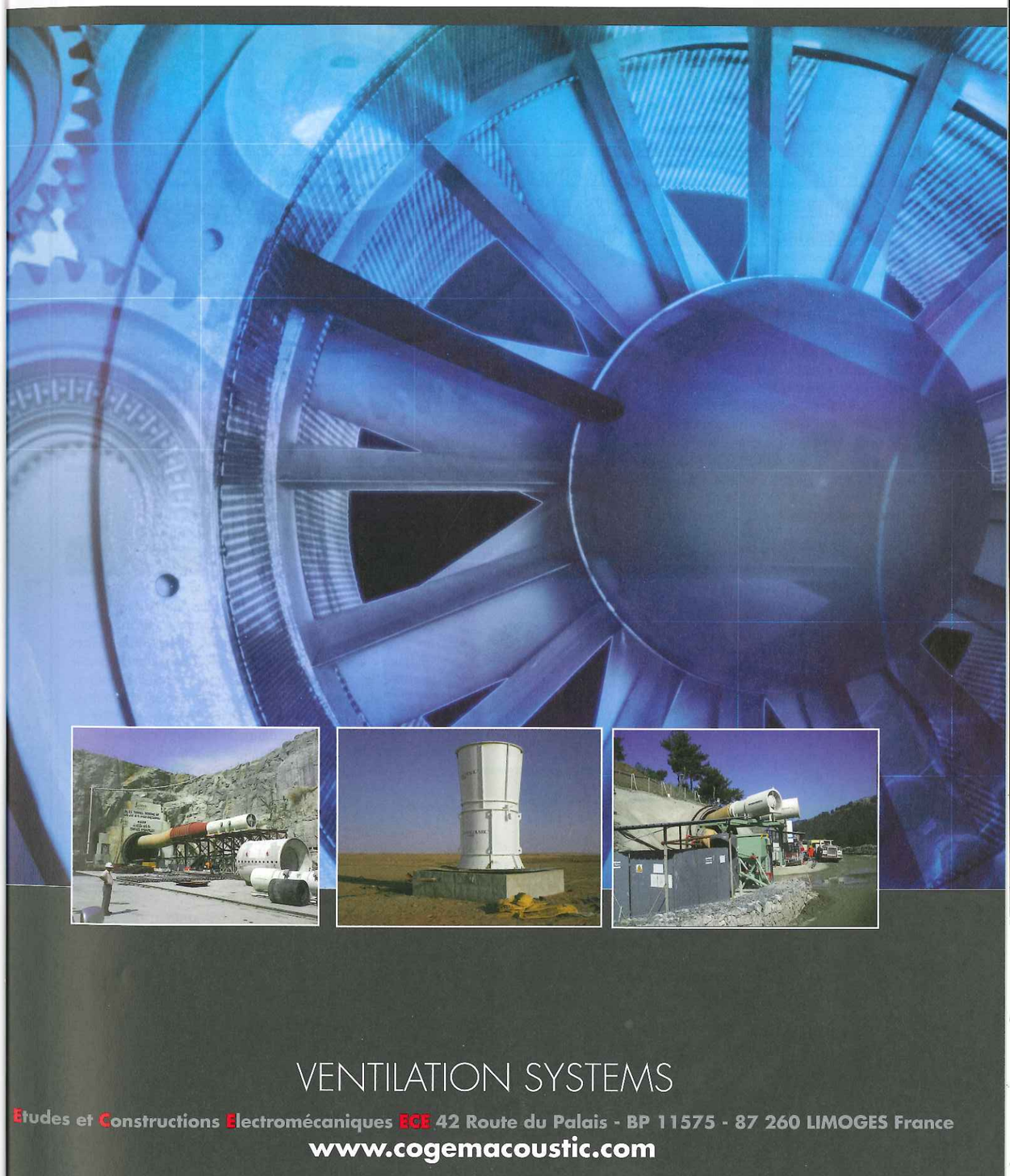
Efforts to improve the finished concrete surface included monitoring and fine tuning placement procedures, testing various form release agents, and minor adjustments to the mix design. Variables associated with placement include injection ports, which ones and how often they are switched; and vibrator use sequence and duration. Several form release agents were tested to see if a water-based product could be found to further reduce bug holes. Oil based form release agents were not used as residue would create a slip hazard on the slope.

Adjustments to the concrete mix design primarily included minor changes to the slump, entrained air content, and various workability admixtures of the concrete. The fine tuning efforts had little effect on the rate of bug hole formation but did result in more efficient placing procedures and consistent concrete mix. The finish was also more consistent, though it still did not meet the finish requirements.

Regardless of the highlighted struggles, the methodology and use of the full round form proved to be an effective choice for this project. The challenging slope was managed and a round concrete surface meeting the structural, shape, and alignment requirements was produced. Very little remedial finish work beyond the patching of bug holes was required

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OBSERVE AND REPORT

The Southeast Collector sewer under excavation in York requires 18 different shafts. Groundfreezing became imperative for the project at a TBM launch site when unanticipated boulders hindered slurry wall installation. **Joseph Sopko** and **Robert Chamberland** of *Moretrench* report



Joseph Sopko
Joe is director of ground freezing at Moretrench and has 30 years experience in geotechnical construction



Robert R. Chamberland
Robert R. Chamberland is a project engineer at Moretrench. He has assisted Sopko on freeze jobs since 1997

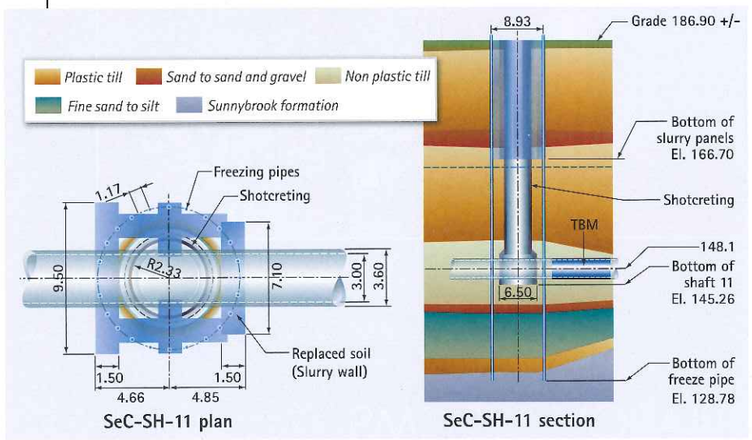
THE SOUTHEAST Collector (SeC) Gravity Trunk Sewer is a 15km, 3m-diameter tunnel currently under construction to augment the existing York Durham Sewage System (YDSS). This system is required for the anticipated population growth in Ontario's York Region. The tunnel is being constructed with four EPBMs and the project has a complex system of 18 shafts, of which 16 and three braced excavations were constructed in advance of the tunnel drives. The overburden soils at the site consist of preconsolidated glacial till and glaciofluvial gravel, sand, silt and clay deposits underlying Ordovician-age bedrock.

Active dewatering was not acceptable for the project due to concerns with affecting the existing groundwater table. Several different approaches to constructing the shaft were used including secant piles, slurry diaphragm wall and shotcrete lining, and in some cases, combinations of these approaches.

One of the critical work shafts required on the project was Shaft 11, which was a TBM access and maintenance shaft. This was a 4.65m outside diameter shaft, extending to a depth of 42m. A profile section of the shaft is illustrated in Figure 1.

The proposed excavation support system shown in plan in Figure 1 was a slurry wall panel approach. The intial plan was to construct the slurry panels as shown, excavate the circular shaft and line the shaft with shotcrete as the excavation progressed.

During the excavation of the slurry panels, a combination of very hard soils and and unanticipated boulders delayed and came very close to stopping the slurry wall installation. At this time, the contractor terminated the slurry panel construction at 20m and evaluated other options to provided the temporary earth support and groundwater control to complete the excavation and shaft



SeC-SH-11 plan

SeC-SH-11 section

construction. The slurry panel depth of 20m would prevent inflows and instability from the upper aquifer in the soil profile.

Ground freezing was proposed as a method to not only provide lateral support and groundwater control but also provide bottom stability by penetrating deep enough and 'keying into' the underlying Sunnybrook impermeable formation. Preliminary evaluation of the soil profile and comparison with frozen soil parameters from other projects indicated that in these soils the frozen earth wall could provide excavation support for the entire depth without any need for additional lining.

The ground freezing process would include mobilization, drilling and installation of freeze pipes as well as an estimated six to eight weeks of freezing. Of particular concern was the six- to eight-week freezing time, when there would be no shaft or tunnel production.

To minimise delays, the contractor decided to proceed with the excavation of the plastic till to a depth of 28m during the formation of the freeze. To avoid any delay in construction schedule, without waiting for the formation of the freezing, it was decided to proceed with excavation and shotcrete from the surface to a depth of 28m, which was located entirely in plastic till with the exception of a 3.2m layer of sand to sand and gravel (stratum 2), which had been already cut off by executed slurry panels. Just before starting of the excavation of the shaft, required freezing pipes were installed and connected to a mobile refrigeration plant and the freezing formation process was initiated.

As the frozen barrier continued to form to secure the deeper parts of the shaft, excavation proceeded in the top 27m with shotcrete being applied concurrently with mining.

The shotcrete had been originally designed to be resistant to ground and water pressure after de-activation of the freezing. Because of the freezing application an extra 50mm of shotcrete was applied to provide an insulating layer to protect the freeze.

Another issue, unique to the freezing process was the development of stresses between the existing panels and the shotcrete line. During the excavation, the soil in that would be unfrozen. At some point after the application of the shotcrete, the soil would freeze, expand and generate stresses against the shotcrete liner and possible damage this temporary lining.

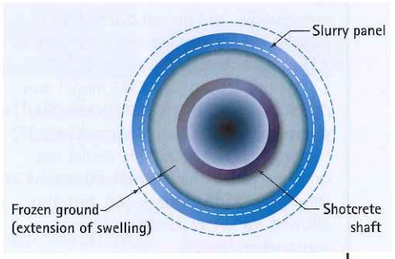
This is different from the deeper phase where the shotcrete would be applied after freezing and expansion. A detailed analysis was required to evaluate the soil structure interaction during this phase.

The first step in most freeze designs is the structural analysis. In this phase the thickness of the frozen earth wall surround the excavation is determined. The thickness of the frozen earth wall is governed by several components, the lateral earth pressure acting on the frozen mass, the compressive strength of the frozen soil, the temperature of the frozen soil and the length of time the excavation will remain open before lining.

18
Shafts are required on the 15km long tunnelling project

50
Millimetres of shotcrete provided a protective layer of insulation for the freeze

20
Metres deep into the slurry panel excavation the contractor stopped to explore other options for the 42m deep shaft



Frozen earth behaves plastically, exhibiting time and temperature dependent rheology. The following were believed to be the most important factors to evaluate to determine the structural geometry and approximate state of stress that may be developed within the frozen earth structure:

1. The approximate frozen wall thickness and related state of stress in the cylindrically shaped structure; and
2. The allowable excavation time before the final lining is installed.

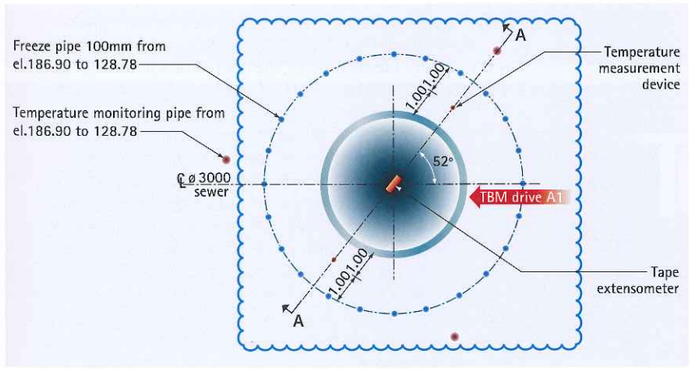
On this shaft both conventional and numeric analyses were used. The conventional methods using closed form solutions have been found to be

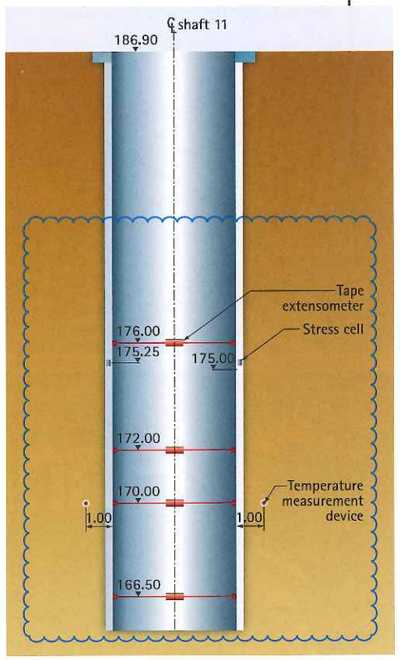
Opposite: Figure 1, Shaft 11

Above: Figure 2, part of the PLAXIS model

Right: Figure 3a, Ground freezing monitoring section view

Below: Figure 3b, Ground freezing monitoring plan view





conservative and do not adequately address the deformation or pressures against the shotcrete wall.

For this reason a PLAXIS model was developed to evaluate the stresses and potential deformation and cracking of the applied shotcrete. This model not only computed the internal stresses of the frozen and unfrozen soil, but also allowed for the expansion of the pore water when frozen.

The PLAXIS model shown in Figure 2 is a simplification of the slurry panels. While the panels were actually rectangular, a cylindrical model was used to take advantage of symmetry. Pressure created against existing structures is frequently an issue in ground freezing and often very hard to evaluate. In this case, it was a critical issue as the shotcrete was not reinforced and while cracking could be tolerated, total failure was certainly not acceptable.

Prior to the shaft construction, several geotechnical borings were taken and relatively undisturbed samples were retrieved. Several sealed samples were still available for further testing. Simple tests to evaluate frost expansion were conducted in a geotechnical laboratory. Precise measurements of the sample lengths and perimeter were taken upon extrusion from the sampling tubes. The samples were then frozen, and the measurements taken again. From this data, it was possible to estimate volumetric expansion of the soil upon freezing. For the plastic till, it was determined that the average expansion was approximately 1.1 per cent.

This expansion was included in the PLAXIS model, and showed that cracking would occur, but not to the extent that there would be excessive damage to the shotcrete. The model also indicated that there was the potential for cracking in the shotcrete lining at depths below the slurry panels. This cracking would be the result of freezing expansion pressure in the deeper soils as well as minimal deformation of the frozen soil upon excavation. While these deformations were also considered acceptable to the overall project, it was deemed necessary to monitor the stresses and deformation in the lining to alert the contractor of deformations greater than anticipated by the modeling. A series of pressure meters between the soil and shotcrete were installed as shown in Figures 3a and 3b.

Figure 4 shows the measured deformation in the interior of the shaft. The deformations that were measured were similar to what was indicated in the PLAXIS analysis. An unusual aspect of this data is that the sand material seemed to deform at a greater rate than the fine-grained till. This is contrary to conventional thinking, however the author cautions that generalized conclusions should not be reached, absent frozen soil laboratory compression tests.

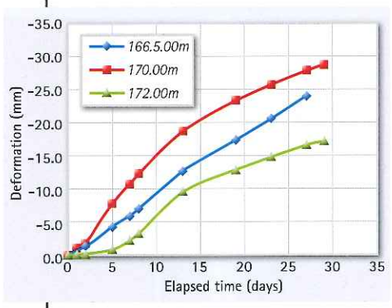
Of important consideration of this project is the useful information gained by the pressure cells. Referring to Figure 5, it can be observed that the pressures increase with time. It should be noted that there was an equipment issue on the Radial South instrument that resulted in data loss.

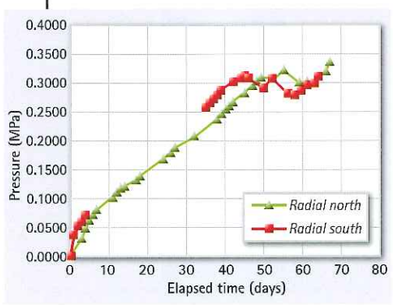
Figure 5 demonstrates that the pressure continued to build. By day 51, the contractor was concerned that the pressures were too high and could damage the lining. In an effort to reduce this pressure, the circulating calcium chloride coolant was warmed from -35 to -10 degree Celsius. Pressures immediately began to decrease. This information provides two very important considerations that can be applied to future freezing projects.

Perhaps the most important consideration is that the data shows that it is possible to decrease frost pressures against structures once a frozen earth wall is formed stresses can be reduced by simply increasing the brine temperature. This process can be applied to many potential future projects.

Another important aspect of this data is the interpretation. A preliminary observation of the data would indicate that the pressures in the lining increased because of the long-term weakening of the frozen earth.

However, the fact that the pressures decreased with increasing brine temperatures show that the pattern is reversible and more attributed to the increasing growth of the soil mass. This means that on future projects, ice growth can be controlled somewhat with temperature and possibly flow adjustments. What should be most apparent on this project, however, was that control of the pressures was only possible due to the presence of data obtained by the pressure meters and extensometers. This data provided the information to observe situations, make adjustments and ensure a safe, successful project





Left, top: Figure 4, Deformation vs. time

Left, bottom: Figure 5, Pressure vs. time.

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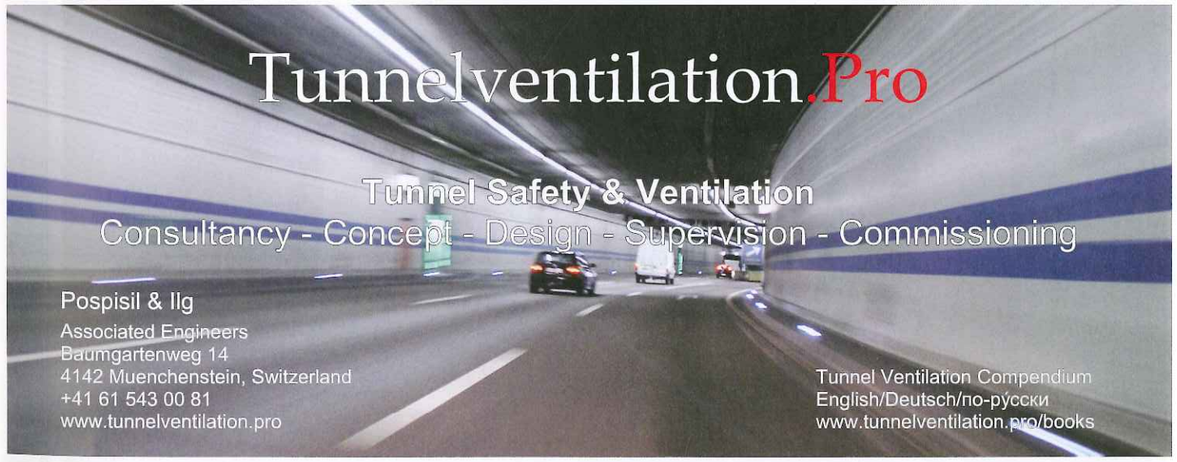
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CLEAR AIR, CLEAR CONSCIENCE

Limited resources and administrative uncertainty can throw up some difficult safety decisions. The directors of *Pospisil & Ilg Associated Engineers* provide some advice



Petr Pospisil
Petr has over 20 years in plant engineering, tunnel ventilation and safety



Ludwig Ilg
Ludwig is a mechanical engineer with over 25 years of ventilation experience

WHEN TALKING with employees of tunnel investors and operators, as well as the responsible government bodies, an uncertainty over the correct course of action sometimes emerges. Doubts about having taken the right decision on safety systems, and fear of possible personal consequences from failures and tunnel disasters can haunt the decision maker's sleep.



For investors, operators and the designers of road tunnels – who bear a responsibility for the safety of persons, as well as for important investment decisions – ventilation is one of the most important systems that enhances the safety of a tunnel. Particularly for long tunnels with high traffic volume.

Lessons have been learned from several road tunnel fire disasters 15 years ago, and a number of new safety requirements have been introduced since then [3]. Today most ventilation systems are designed primarily for an emergency situation, i.e. the fire ventilation, and many are hardly ever used in normal operation. Improvement is a continuous progress, and after more than a decade of practical application of those new safety standards, new findings and the actual state of the art of technology should be taken into account.

Another sleep-depriving fear for tunnel stakeholders is the fact that the excessive costs of road and rail infrastructure are being brought into question in many countries. Political pressure leads to cuts in budgets, and many tunnel projects are postponed or even cancelled for this reason.

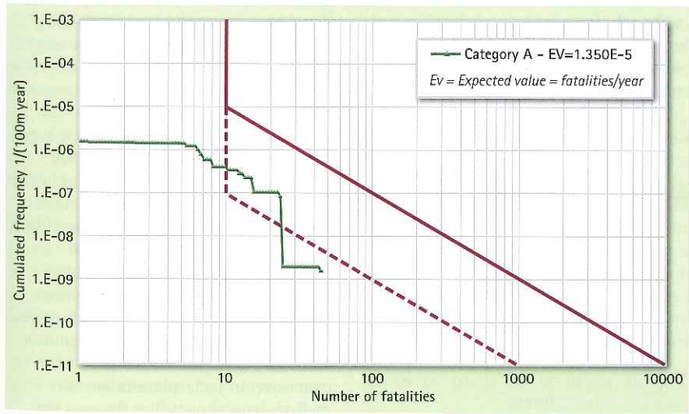
Prescriptive guidelines for tunnel safety equipment, particularly for ventilation, do not always lead to useful solutions. When safety requirements lead to the construction of a tunnel being delayed, or even cancelled due to financial restraints, then those requirements might be questioned and compared with the primary benefits of the tunnel itself, like improving traffic safety and capacity by optimising road alignments, or reducing the environmental impact in comparison with an open road. Considered from this perspective tunnel safety regulations that delay or prevent projects do indeed decrease the road safety in the long term.

Two important measures to increase safety and reduce costs of road tunnels are described in this article. The first is a proper risk assessment, based on scenario analysis, to support useful conceptual decisions. The second is rigorous and continuous testing to ensure that those costly safety measures fulfil their purpose in practice. Only testing allows us to identify systems with limited or not even existent usefulness. It enables us to improve or omit that kind of technology in the future.

These aspects have been more or less ignored in many prescriptive design codes that have been revised in the aftermath of the 1999 tunnel fire disasters. In fact, any requirement in a guideline is useless when its fulfilment cannot be proven.

Recent guidelines, for instance the new Czech methodical instruction for road tunnel ventilation [4] include risk based decision-making and requirements for testing procedures in order to achieve an acceptable level of reliable functionality.

Below: Figure 1, Sample frequency-consequence diagram with lines of acceptance



That guideline was worked out for the Czech ministry of traffic, but has been based on practical experience from more than 100 tunnel ventilation projects worldwide.

RISK ASSESSMENT AND SCENARIO ANALYSIS

Cost-benefit considerations should be part of any decision about safety of human lifes and investment of billions of Euros. The often-heard statement "each life has to be saved at whatever expense" is practically infeasible given limited funds [9].

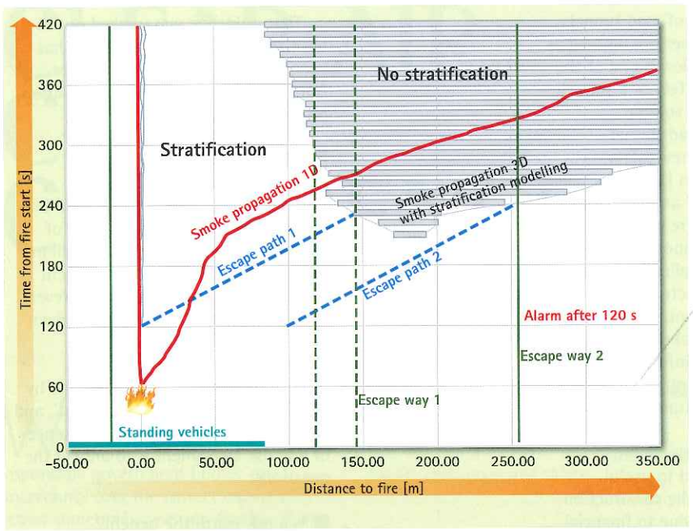
Safety measures should be assessed by their costs and benefits by estimations of 'costs per life saved', and 'cost of avoided damage'. The essence of any risk assessment is to answer the questions:

- Is a risk worth the benefit?
- Are risk mitigation measures worth the resulting risk reduction?

Many risk analysis studies for road tunnels have been worked out in the recent years, a number of simulation models have been established and a lot of literature has been written about the issue. A good overview can be found in the PIARC document [2]. One of the major findings is that the safety in a road tunnel is governed in first order by the risk of collisions and only in second order by fire risk. There are only a few tunnels where fires occur with a statistically relevant frequency, and the vast majority of fire incidents do not lead to casualties. In fact, in comparison with overall road traffic casualties, those from fires in tunnels are negligible. In 2012 , there have been approximately 28'000 fatalities on roads in the European Union [11], while the fatalities due to road tunnel fires worldwide in the last 100 years sum up to a number in the order of 150 (at least in peace times) [8]. Approximately 25 per cent of those died in one single event, the 1999 disaster in the Mont-Blanc tunnel between France and Italy, and many deaths were caused by the accidents leading to the fire rather than by the fires or the smoke.

Obviously the new safety regulations may contribute to a higher level of fire safety in tunnels, but this is not a guarantee that a huge disaster could not happen just the next day.

For an applicable risk assessment, first of all the main goals of any safety measures must be defined, and clear criteria must be stated whether those goals are met. In this way, limiting lines



in a frequency-consequence-diagram (F/C) are created.

For risk mitigation, measures that prevent accidents are much more effective than measures that affect only the consequences. In this aspect, the purpose of tunnel ventilation to provide clear visibility in the tunnel could have a higher importance than fire ventilation. This aspect is important for long tunnels with bi-directional traffic and high traffic volume.

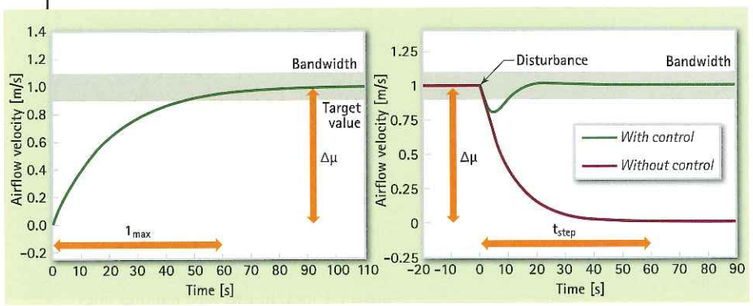
The key element to assess fire risk in a road tunnel is a scenario analysis based on dynamic simulation of smoke spread and escape of persons. Different variants and boundary conditions lead to dozens or even hundreds of simulations to be conducted. 1-D models are useful for fast computations, but for the assessment of smoke stratification, which might be essential in certain cases, 3-D modelling of the airflow in the tunnel is required.

Assumptions on useful boundary conditions may have a strong influence on the results. Particularly sensitive to this is the longitudinal airflow and spread of smoke in the first phase of a fire, before the fire is detected and the fire ventilation is started.

Any risk analysis is based on simplification. The result of even complex, detailed risk analysis is still a rough estimation, taking into account the limited data, unknown probabilities and simplifications of modelling. Simulation results should be double checked by using a common sense approach. In that aspect, common sense can be achieved through practical experience. Expert knowledge can assure that reasonable assumptions are applied. Therefore, such scenario analysis

Above: Figure 2, Example diagram of smoke propagation and escape paths

Below: Figure 3, Acceptance criteria for control of longitudinal airflow



An additional tube to allow unidirectional traffic is much more efficient than an escape tunnel

should be conducted or at least supervised by experienced engineers. Such can be identified by having a proven track record of planned, realised and successfully tested reference projects, with focus on thorough testing.

Even when the underlying probabilities and models are to be understood only as rough estimations, the instrument risk analysis provides a good idea about the magnitude of the risk that is to be expected. It may serve as basis for decisions about useful risk mitigating measures.

As an example, escape ways rank among the most important safety measures. They significantly improve the ability of the tunnel users to escape in case of a fire. For instance, the European guideline [4] requires escape ways in distances not exceeding 500m for tunnels on the trans-European road network.

However, the determination of useful distances between escape ways is very dependent on the context. Scenario analysis based on simulations of smoke propagation and escape of persons have shown that to be effective in tunnels with bidirectional traffic, the distance should not exceed approx. 150m, when the tunnel is going to be filled with smoke. Particularly in connection with strong longitudinal airflow, smoke is spread quickly over considerable distances even before any detection occurs and fire ventilation would react. The need for escape ways from the tunnel at short distances has been confirmed by the author's personal experience [8].

Considering the costs of escape ways, numbers spread widely. For cut and cover tunnels, with two tubes and just a dividing wall, the connections between the tubes are almost for free. Therefore, such connections can and should be placed at short distances without excessive costs. Connections between two bored tunnel tubes are much more expensive, and separate escape tunnels for single tube tunnels are even more expensive. In fact, quantitative risk analysis have shown that the cost per

life saved for separate escape tunnels lies in the magnitude of billions of Euro. In terms of cost per life saved, the construction of an additional tunnel tube to allow unidirectional traffic is much more efficient than any parallel escape tunnel, because it significantly reduces the collision risk and subsequent fire risk.

Of course, such considerations are subject to political decisions. However, you cannot always predict the future by taking into account past experience. Using the term 'worst case' is questionable. In practice, worst case scenarios always occur, ones of which nobody has previously thought of. It is usually only after such an incident that public opinion may criticise the lack of appropriate measures. The decision process requires some courage from the authorities when looking for useful solutions. Maximum provisions cannot be relied upon just to avoid blame [9]. In this aspect, sleeping well cannot be justified by spending excessive money on safety measures with questionable usefulness.

THE IMPORTANCE OF TESTING

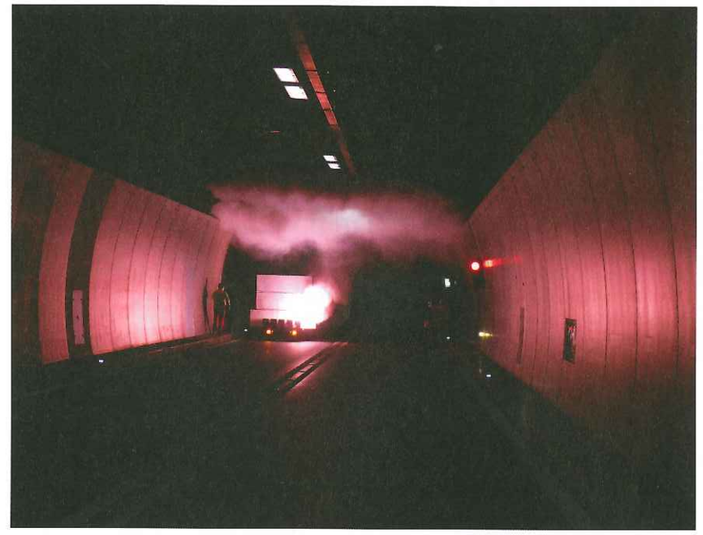
A concept or system which is completely inapt might last for long time as long as it is never really tested. That is the case for many safety systems (e.g. tunnel ventilation equipment) that are built for extraordinary events, which probably never happen. In fact, most tunnel ventilation systems as designed before 1999 were not useful for fire ventilation.

Defects in safety systems that are practically never in operation become first visible when an incident occurs, but then it is too late – the failure can have disastrous consequences. Uncertainties about this issue rightly cause bad sleep. Therefore, all functions and operating states of the safety systems should be tested as realistically as possible but with justifiable efforts. Experience shows that during the tests a lot will go wrong and needs to be corrected. This demands time and costs which rise disproportionately with increasing complexity.

This is a strong argument for the KISS principle (keep it simple, stupid): simple technical concepts should be aimed for. The error rate grows with increasing complexity and the overall safety decreases.

An investment in smart engineering can save a hundredfold in project costs (and hours of sleep lost to worry).

Most important is to understand that





Above: Smoke testing exercises underway in tunnels

the purpose of testing is not to demonstrate that everything works fine, but to find faults that are to be eliminated.

What is not tested cannot be assumed as safe. Although the costs for tests are comparably low, due to continuous time pressure and financial shortcuts in the final stage of any project, testing is often neglected.

Psychological aspects counteract safety considerations. Because incidents occur very rarely, the common attitude is that nothing would happen, and there is no money for testing, even when previously dozens of millions of Euros might had been invested in safety equipment and structural provisions without questioning.

People usually assume that everything would work fine and ignore in particular their own mistakes. Experienced practitioners know better. To err is human and errors always come up.

The more and profound you test, the lower becomes the probability of unpleasant surprises in operation. Investment in

testing lets you sleep well as a tunnel investor, operator or safety officer.

The control of the spread of smoke is the main goal of the fire ventilation. To achieve this, detailed test scenarios for all possible states of the control system must be defined, including failure modes, breakdown and malfunction of equipment.

For each of these scenarios, acceptance criteria should be defined. Tests probe the function of single systems – like the ventilation – as well as the integral cooperation of all tunnel safety systems.

The key element of state of the art fire ventilation in tunnels is an effective control of the longitudinal airflow. With or without smoke extraction, a fast stabilisation of the airflow at low flow velocities, lower than the assumed walking speed of persons, assists escape and enables smoke stratification. This is important in tunnels with bidirectional traffic or where congestions are common. However, this does not apply to highway tunnels with free flowing unidirectional traffic.

Acceptance criteria for the control of longitudinal airflow, based on realised ventilation systems, have been proposed [7].

Calibration of instruments and testing of equipment and control systems should also be repeated in regular intervals for tunnels in operation, together with proper service and maintenance work. This is often neglected however, leading to expensive equipment becoming inoperative after only a few years.

An important part of testing procedures are realistic smoke tests. From the two main effects of fire, smoke and heat, the latter leads to significant structural damage and cannot be simulated without extensive, costly protection measures. On the other hand, the smoke kills and injures most people in fire incidents, and it´s propagation can be simulated and visualised relatively easily.

Realistic smoke tests to be applied for testing of tunnel safety equipment should fulfil the following requirements:

- The physical characteristics of the test smoke, especially the optical density should be similar to that in case of a real vehicle fire.
- The produced heat must not damage the structure and equipment in the tunnel but should induce thermal buoyancy and smoke stratification.
- The test smoke must be harmless with regards to toxicity and possible health hazards.
- The test smoke must not be corrosive and must not leave behind any deposits on the installed equipment in the tunnel, particularly on measuring instruments and cameras.
- Influencing boundary conditions for the longitudinal airflow in the tunnel (traffic, wind, buoyancy) must be simulated.
- The smoke detection must react reliably, even with an active fog suppression.
- Tests should be carried out simply and quickly, to carry out tests for many different scenarios.

Realistic smoke tests show the function of the automatic smoke detection and the performance of the fire ventilation. A realistic view of the situation in a fire emergency is given to the present professionals, including investors, designers, operators and fire brigade. Most importantly, you often find issues that nobody has thought of previously.

Through this, precious findings for a continuous progress and improvement are achieved, which should be considered in the concept and design process. This is important where requirements in actual design guidelines were based mostly on mere theoretical considerations.

Finally, when decisions, particularly about appropriate ventilation and safety systems, are based on careful considerations and risk analysis, and proper function with sufficient reliability of those systems has been achieved by a process of thorough testing and improving, then the stakeholders like tunnel investors, operators and designers can sleep well with a good conscience



Below: Smoke exhaust damper in action

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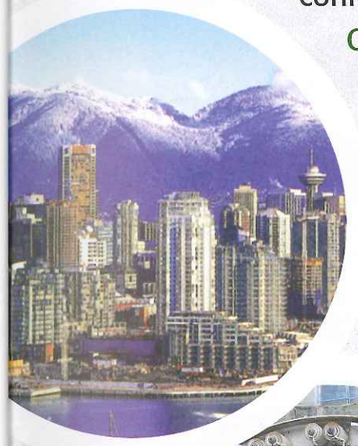
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TOP OF THE BOX

Bangkok's metro system construction is making innovative use of pipejacking for the roof of a new underground station reports **Adrian Greeman**

PIPEJACKING IS a useful technique for more than just service installation. On the new Blue Line metro extension in Bangkok it is being used for top down construction work, with interlinked pipes forming a roof structure 275m long below which excavation can proceed.

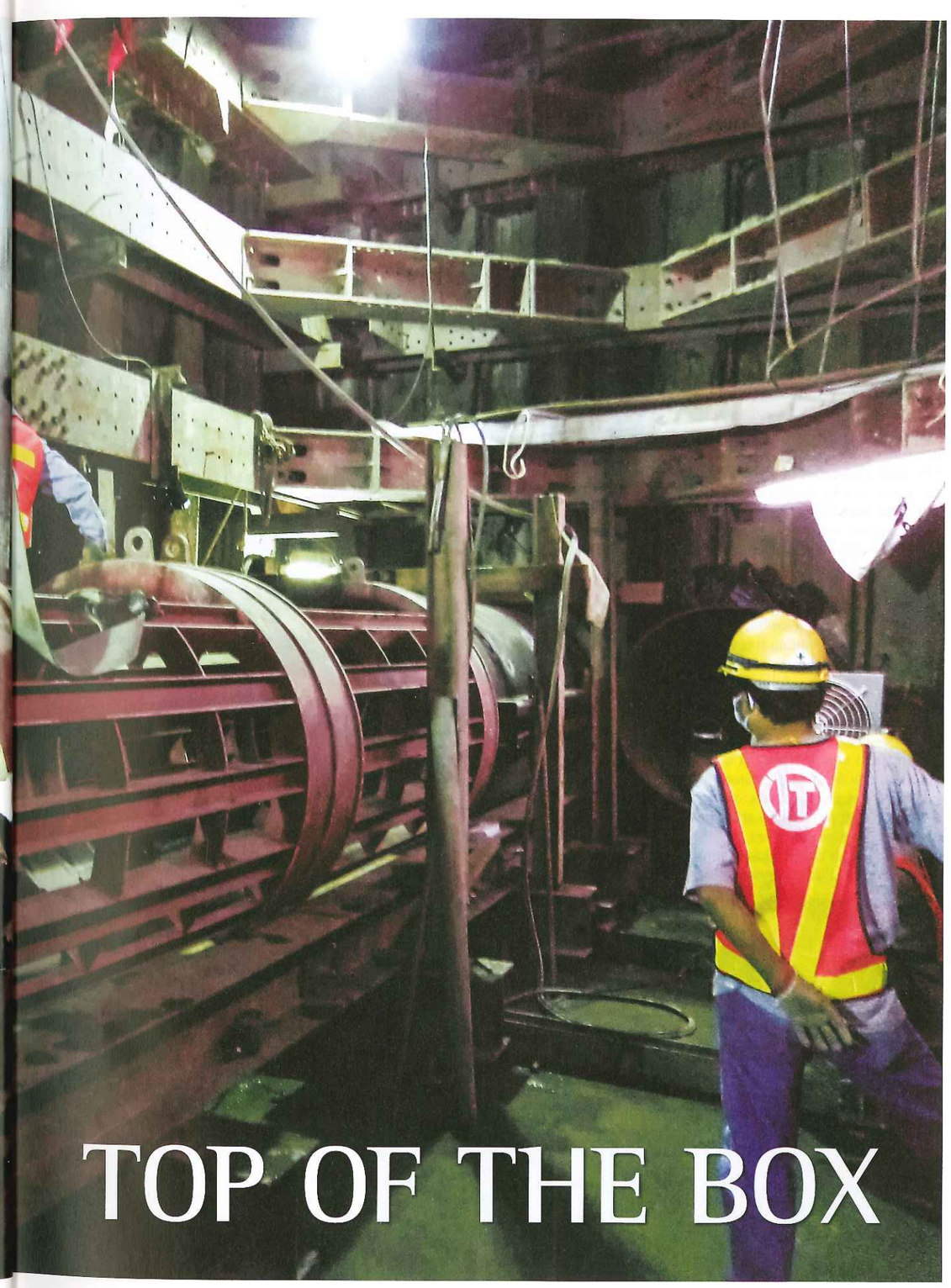
Jacking has been used this way in the past for making adits and underpasses in countries like China, Singapore and Germany but local contractor Ital-Thai Development (ITD), one of the country's largest firms, thinks it is possibly the biggest project of this kind. It is certainly the first use of the "piperoof" method in Thailand says the ITD project director Pairach Supavivat.

The contractor has developed the method to solve a specific problem on the extension work for the Blue Line underground metro. The city's first underground line was opened ten years ago with a C-shaped route on the east side of the Chao Phrya River finishing at the central railway station. Client, the Mass Rapid Transit Authority of Thailand, now wants to complete the line as a circle, filling in the western side gap in the route. First part of the work is a 5.4km long underground extension across the river with four new stations, let in two halves. Later an elevated line will finish the route. The new tunnels will carry the southern end of the route just 300m away from the historic buildings of the royal city areas and through the well known Chinatown district. That makes challenging work for ITD on the first 2.5km length. Although one of its deep stations can be built by conventional excavation within diaphragm walls the other, Wang Burapha, is potentially in archaeologically important ground. The city authorities have banned any excavation of the top 5m of undisturbed ground where relics might exist. The ban also helps maintain traffic in the street above, which is very important in the often congested city.

The contractor is allowed excavation



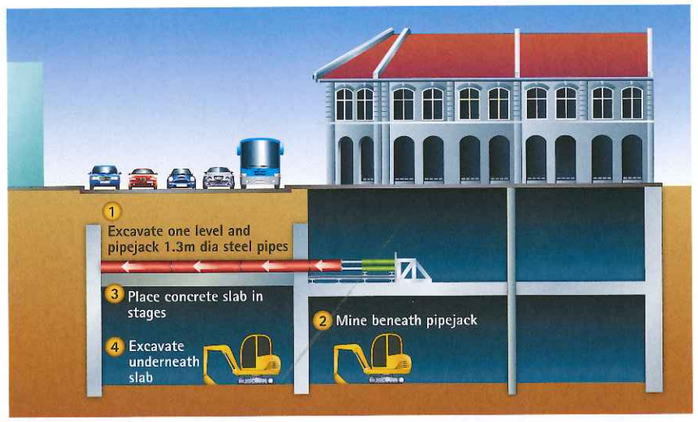
Right: The contractor used two hydraulic cylinder jacks each of 100t capacity

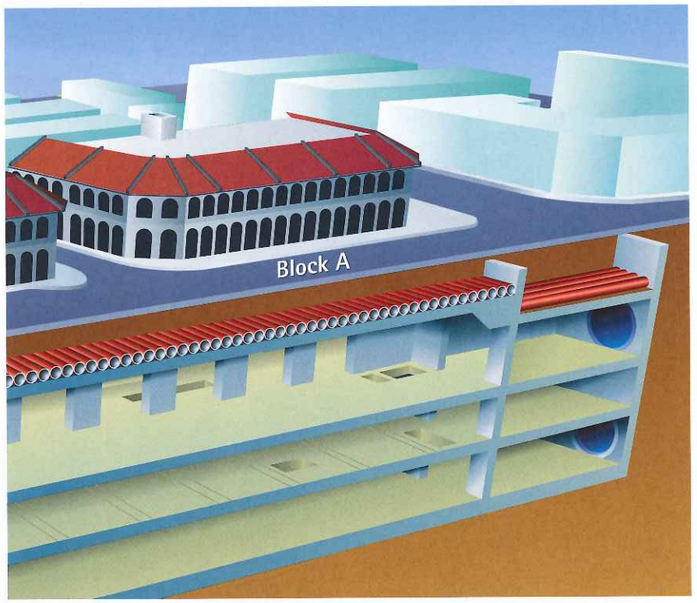


Adrian Greeman
Is a former editor of and long-standing regular contributor to *Tunnels*







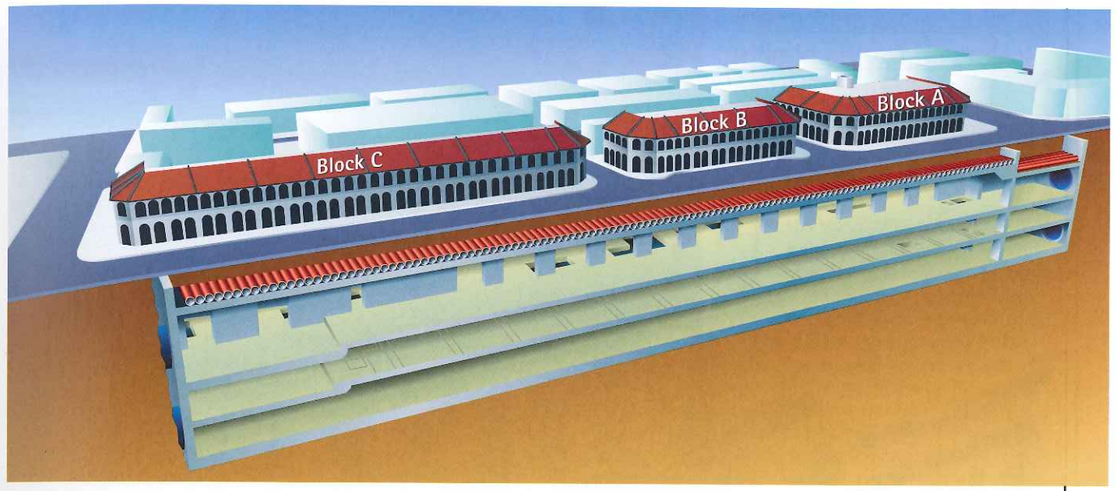


to the side of the road where part of the station will replace older buildings and during the 2010 tender stage, looked at enlarged diameter tunnelling to make the station platforms under the road, but then it turned to the piperoof solution as a better option. Essentially the plan was to form a new roof under the road by jacking from the excavations to the side. With a pipe roof in place a concrete slab could then be formed on the underside, embedding the jacked pipes and below this excavation could proceed leaving the ground above untouched.

The scheme devised is for a diaphragm wall construction through Bangkok's very soft clay ground and into stiffer clays and a sand layer below. Under the building this would be excavated to make a working space to set up a jacking rig frame tied to a central diaphragm wall. The method uses 1.3m diameter steel pipes running across the 12.8m wide space for the station tracks and platforms. It is kept this narrow to fit under the street above, with platforms one above the other. It means the twin tunnels will arrive in a stacked formation. The pipes are pushed across the gap in a parallel formation along the entire 200m length of the station. ITD, which has substantial pipejacking experience anticipated this would be relatively straightforward in the city's notoriously soft clay ground. "We are using two hydraulic cylinder jacks of 100t capacity each" says Pairach. "They are used with a total jacking load of about 40t."



Mucking out is straightforward using a half bucket system, with a pulley wire for drawing it back, to remove the spoil. The pipes are big enough for man entry if any obstacles occur. The most complex part of the jacking is keeping the pipes on line, not least because they have to be connected together; for this a clutch system is being used a little like that on sheet piles. The clutches are welded onto the sides of the pipes. Details for the clutch design were worked up



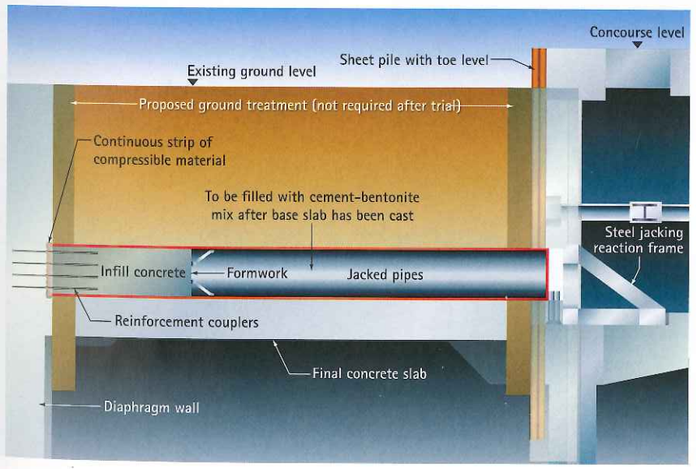
in conjunction with a Singapore consultant GX Tunnel & Environ Services. Pairach says that he does not anticipate any great difficulties with this because the distances are relatively small. "Standard surveying methods for vertical and horizontal direction should be sufficient with adjustments by the four jacking forces."

To be sure, the company ran a trial last year at the station site itself, making a small temporary shaft when the diaphragm walls were being done and jacking two pipes. These will be incorporated into the final roof. The most complex detail has been how to make the connection at the far end to the diaphragm wall there. ITD has worked on this detail in conjunction with its designer, the Hong Kong office of consultant Arup International. The consultant is part of the design and construct team. "Initially we considered ground treatment in front of the diaphragm wall by perhaps soil mixing" says Pairach, however during the trial runs the team decided that this preparation would not be needed.

But the rest of the connection method remains as planned, using couplers embedded in the diaphragm wall to link to dowel bars which are cast into a concrete plug at the end of the steel pipes. "The ends of the pipes are jacked until they reach the diaphragm wall on the opposite side of the station"

Opposite and above: Figures 1-3, The 1.3m diameter steel pipes are pushed across the gap in parallel formation along the entire 200m length of the station. With the piperoof in place a concrete slab can be formed beneath embedding the jacked pipes

Below: Figure 4, Construction of the piperoof



The plan was to form a new roof under the road by jacking from the excavations to the side

he explains. Here there is a compressive pad cast into the diaphragm wall panel and the pipes push into that to minimise the ingress of water and soil at the far side.

With that done and the ground sealed the face of the diaphragm panel can be broken away to reveal the couplers and make the links. Formwork is set up inside the pipe and a 3m length of concrete is then cast into the end of the pipe making the connection. The first, or rather the third pipe after the trial pipes, was jacked into place at the beginning of December and installation is currently proceeding along the roof length. Once that is finished the slab will be formed. To do this ground will be excavated underneath the roof and then formwork on a hydraulic jacked frame will be positioned and concrete pumped in. That forms a composite roof structure below which normal top down construction will continue to make the two tracks and platform boxes.

The TBM making the tunnels will pass through the end diaphragm walls and be hauled through the station. Meanwhile the other side of the station will also be excavated for the concourses and ticket areas. Above ground there will be a new structure and entrances



MAIDA VALE

Pipejacking is a key part of a flood alleviation project which is set to protect hundreds of properties in northwest London

THIS WINTER has seen flooding hit the UK once again as heavy rains and gale force winds have battered the country. The good news for residents of Maida Vale in northwest London is that from December 2014 sewer flooding will become a thing of the past. "We are disconnecting every property that floods from the existing sewer and redirecting the flow to two new pumping stations," explains Iain Tytler project manager for Optimise. Optimise is a joint venture between contractor J Murphy & Sons, Barhale Construction, Clancy Docwra and consultant MWH and is carrying out the work as part of its AMP 5 framework agreement with the UK's largest water company Thames Water. "In dry weather all sewage will be pumped away immediately, in storm conditions the pumping station will hold the runoff and then we have storm pumps to take the flow away once the rain has subsided."

The works will tackle two major sites of sewer flooding situated approximately 0.75 miles apart that are hardest hit during summer storms where large volumes of rainfall land in a short period of time. "We are removing 177 properties from the sewer flooding database but we think there are up to 350 properties that have been flooded. There hasn't been any flooding here for four years but prior to that there were three flood events," says Tytler.

The 15 month project will see the placement of 1,600m of pipe and two new major pumping stations at Tamplin Mews and Westbourne Green giving an additional 8000m^3 of stormwater capacity. Given that these are situated in much valued green spaces the infrastructure is below ground as much as possible and above ground kiosks are to be constructed in timber to fit in with the park environment. Hexpath grids are being used as ground reinforcement along the vehicle access route as these allow grass to grow within it and retains the green space.

In total 1,180m of the new sewer pipe will be placed using trenchless construction methods and 420m using traditional open cut. Pipejacking of a crucial 98m section that links the new sewer to the Tamplin Mews pumping



station began in November 2013. "The pipejacking ranged from 8m to 10m deep and was running parallel with the road and adjacent to an existing network sewer. The depth and size of the bore made microtunnelling the best solution," says John Raftery, site manager for Optimise. Work began with the sinking of the launch and reception shafts. "The shafts were sunk as 5m underpinned segmental shafts. The drive shaft was underpinned to about 18m and then we had to backfill that up about 5m. The reception shaft was built in exactly the same way and sunk to 10m," says Raftery. There was also a lot of utility diversion to undertake including gas pipes, water mains and power and telecoms cables. After around three weeks constructing the launch pit the team could begin setting up the pipejack. "We constructed the needle for the temporary breakout and built the back thrust wall, and then we got the above ground equipment set up for the microtunnelling and that consisted of the electricity generator, control unit, and a separation plant for cleaning the slurry," says Raftery. Boring was carried out using an Iseki TCC slurry machine supplied by Barhale. This was followed by the jacking in of 1000mm precast concrete pipes from FP McCann. "There were no major issues. Ground conditions were very stiff clay and the pipejack progressed as expected," says Raftery.



The 98m section took 10 days to complete was followed by two days of grouting the pipework. By the end of November the section was complete and the team is now constructing more of the upstream sewers utilising the Guided Auger Boring technique.

By October 2014 Optimise plans to have completed the pipework, 2014 will also see the construction of a 400m long section of 2.44m ID tunnel which will transfer flows to the 25m deep 20m diameter pumping station in Westbourne Green and all work is set to be completed by the end of the year

CUTTING CARBON

A new carbon calculator can now be used to show the benefits of pipejacking versus open cut construction

RESEARCH SPONSORED by the UK's Pipejacking Association (PJA) and delivered by Transport Research Laboratory (TRL) shows that savings of up to 75 per cent in carbon emissions can be demonstrated comparing trenchless pipe placement to open cut. The method uses a new web based carbon calculator: www.pipejackingco2calculator.com which was launched in mid-2013 and evaluates the carbon footprint of pipejacking or microtunnelling compared to open cut placement of sewers and other utilities in urban highways. "This level of savings in carbon emissions was achieved by comparing the installation of 500m of 600mm pipeline, 6 metres deep, using non-disruptive techniques with open-cut construction," says Brian Ashton, chairman, Pipe Jacking Association and director, DCT Civil Engineering. "In this comparison the saving equates to more than 370t of carbon emissions. In addition, the construction period for the trenchless installation was projected to be less than half that of the open-cut construction. At shallower depths carbon savings are more typically in the range of 50 to 60 per cent."

The comparison tool has been developed by TRL and is the third carbon calculator that it has produced to date. Previous projects were conducted for government supported recycling body WRAP comparing primary with recycled aggregate; and creation of the asphalt pavement embodied carbon tool (asPECT) which calculates the carbon footprint of asphalt . "It took just over a year to develop the new calculator," says TRL project manager Matthew Wayman. Wayman is an expert in carbon footprinting based on life cycle assessment. "It is really data intensive so getting all of the required information was quite a task and it required some software development to create the web application."

The tool can compare all kinds of pipe materials in all ground conditions. Data for the calculator has been drawn from a number of authoritative sources that include the University of Bath's Inventory of Carbon and Energy for construction materials, the Concrete Pipeline Systems Association, and outputs from the Department for Transport's QUADRO program (Queues and Delays at Roadworks) also developed by TRL. To complement these data sources the calculator uses a range of datasets that were developed by PJA engineers to enable the application to calculate carbon emissions.

These include:

- Comprehensive materials schedule for all pipe diameters from 200 – 2400mm to include manholes, shafts, base slabs and all other components that impact on carbon emissions
- Plant schedules for both scenarios together with energy usage
- Machinery selection for all diameters in differing ground conditions, using both slurry and dry techniques
- Project duration – realistic outputs and daily hours worked
- Average haulage distances for plant and materials

Table 1. CO_2e Estimates (tonnes)

Feasibility	Open Cut	Pipe Jacking
Material - Pipes/Shafts/Manholes	44.4	77.8
Material - Aggregates	49.0	0.0
Material - Spoil	136.7	14.9
Material - Asphalt	36.7	0.0
Total - Material CO_2e	266.8	92.8
Total - Machinery CO_2e	34.3	24.0
Transport - Pipes/Shafts/Manholes	2.9	4.1
Transport - Aggregates	45.4	0.0
Transport - Spoil	33.7	3.7
Transport - Asphalt	2.4	0.0
Transport - Trench Support	2.3	0.0
Total - Transport CO_2e	86.6	7.8
Total Traffic CO_2e	104.6	0.0
Total CO_2e	492.4	124.6

Source: PJA-TRL

Reports can be produced that not only provide comparative emissions data for open-cut and non-disruptive options, they also detail data sources and assumptions utilised in the calculations.

The carbon dioxide emissions calculator is free to use and has been verified by WRc plc. The PJA says that the new tool will add further pressure to utility companies to consider non-disruptive alternatives at design stage to mitigate carbon emission under their statutory obligations. These obligations include the CRC Energy Efficiency Scheme and Environmental Key Performance Indicators which form part of the Government's commitment to reduce carbon emissions by 80 per cent on 1990 levels by 2050. The Department of Energy & Climate Change's CRC Energy Efficiency Scheme (formerly Carbon Reduction Commitment) is a mandatory scheme aimed at improving energy efficiency and cutting emissions in large public and private sector organisations that are responsible for around 10 per cent of the UK's emissions.

Development of the tool was inspired by earlier work in the US which had been put on hold. The North American Society for Trenchless Technology (NASTT), in association with the Action on Climate Change Team (ACT) of Simon Fraser University in British Columbia had been developing a similar carbon calculator.

The project was then transferred to NYSEARCH, a New York based research group that works on behalf of North American gas and water utilities and the project was then put on hold. As a result the Pipe Jacking Association decided to sponsor a new tool.

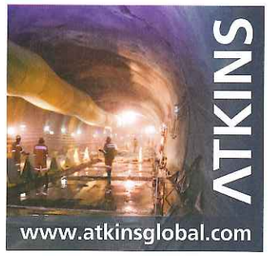
In developing the calculator the PJA established key parameters for the project. These parameters being, that it should be easy to use, transparent, comprehensive, authoritative and verified.

The PJA believes that by using TRL, an international consultancy well versed in all aspects of transport, as contractor, and WRc to verify its integrity and performance, these parameters have been more than adequately met

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What's on

2014

Tunnel Expo Turkey
28-31 August 2014
Istanbul, Turkey
The number of newly-excavated tunnels in Turkey is among the highest in the world, and in Istanbul, a great number of infrastructure tunnels are planned to be excavated soon, worth more than USD 10bn. Demos Faurcilik, in association with the Turkish Tunneling Society, is organising the third short course on tunnelling in Instabul, along with a tunnel technology fair.
www.demosfuar.com.tr

Fire Protection and Safety in Tunnels 2014
10-11 September 2014
Bergen, Norway
Fire Protection and Safety in Tunnels returns after last year's event in Copenhagen, which set new standards for case study, industry driven presentations and networking opportunities. Norway is hosting the sixth annual FPST event, a country with an impressive network of more than 900 road tunnels alone.
www.arena-international.com/fpst

15th Australasian Tunnelling Conference
17-19 September 2014
Sydney, Australia
The Australasian Tunnelling Society's triennial conference, and registration is scheduled to open online this month.
www.atstunnellingconference2014.com

BTS Conference 2014
17-19 September 2014
London, United Kingdom
The BTS Conference has risen to become the UK's largest tunnelling and excavation event, and is the only show supported by the BTS.
www.btsconference.com/content

InnoTrans
23-26 September 2014
Berlin, Germany
An international platform for buyers and sellers of passenger and freight transport technology, InnoTrans focuses on railway technology. The Tunnel Construction segment will be accompanied by the International Tunnel Forum, which will feature a series of international discussions
www.innotrans.de

ExpoTunnel
23-25 October 2014
Bologna, Italy
Following the success of the inaugural exhibit in 2013, with 105 exhibitors. 20 per cent from outside of Italy, and 5,400 visitors, plans are set for the second edition of ExpoTunnel. The event is dedicated to the world of tunnelling, drilling, mining, underground construction and research, and is facilitated in collaboration with the Italian Tunnelling Society (SIG).
www.expotunnel.it

TAC 2014 Annual Conference
26-28 October 2014
Vancouver, British Columbia
The Tunnelling Association of Canada's Vancouver TAC 2014: Tunnelling in a Resource Driven World will include plenary presentations, technical sessions, and a trade exhibition all designed to highlight advancements in tunnelling research and practice from around the globe. This event will include TAC's Annual General Meeting and Awards
www.tac2014.ca

2015

Shotcrete conference and exhibition
29-30 January 2015
Tyrol, Austria
Wolfgang Kusterle and his team welcome you to the Conference and Exhibition Shotcrete 2015 at the Alpbach Conference Centre. Knowledge and experience do not help, if they remain hidden. This platform has gathered shotcrete specialists for 25 years, in a surrounding field where the exchange easily takes place.
www.spritzbeton-tagung.com

ISRM Congress 2015
10-13 May 2015
Montreal, Canada
Held in conjunction with the CIM Convention for 2015, the International Symposium on Rock Mechanics holds its international conference every four years. A one day symposium on "Shale and Rock Mechanics" is planned.
www.ISRM2015.com

World Tunnel Congress 2015
22-28 May 2015
Dubrovnik, Croatia
WTC 2015 heads to the Dalmatian Coast as the event returns to Europe. Further details to be confirmed.
www.wtc15.com

RETC
7-10 June 2015
New Orleans, Louisiana
The Underground Construction Association's biennel conferece.
www.smenet.org

25th World Road Congress
2-6 November 2015
Seoul, South Korea
The World Road Congress has been held every four years for more than 100 years. It tours the member nations of PIARC.
www.aipcrseoul2015.org

British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Events are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month.

Crossrail Western Tunnels, urban tunnelling through the capital
18 September 2014
This presentation will cover the whole development of the Crossrail Western Tunnels, from design, through procurement and to construction and successful completion. Andy Alder of CH2M Hill, Adrian StJohn of BFK and Stephan Fleischman, also BFK, will speak. This presentation will be given as part of the BTS Conference 2014.

"What could possibly go wrong with a site investigation in chalk?"
16 October 2014
A review of case histories and the importance of site investigations and particularly the analysis of the results. To include case histories of good and bad practice. The speaker is Rory Mortimer, Brighton University.

If you have a topic or project you feel would be suitable for a BTS presentation, please contact greg.james@ice.co.uk or daterry@bssujv.com

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