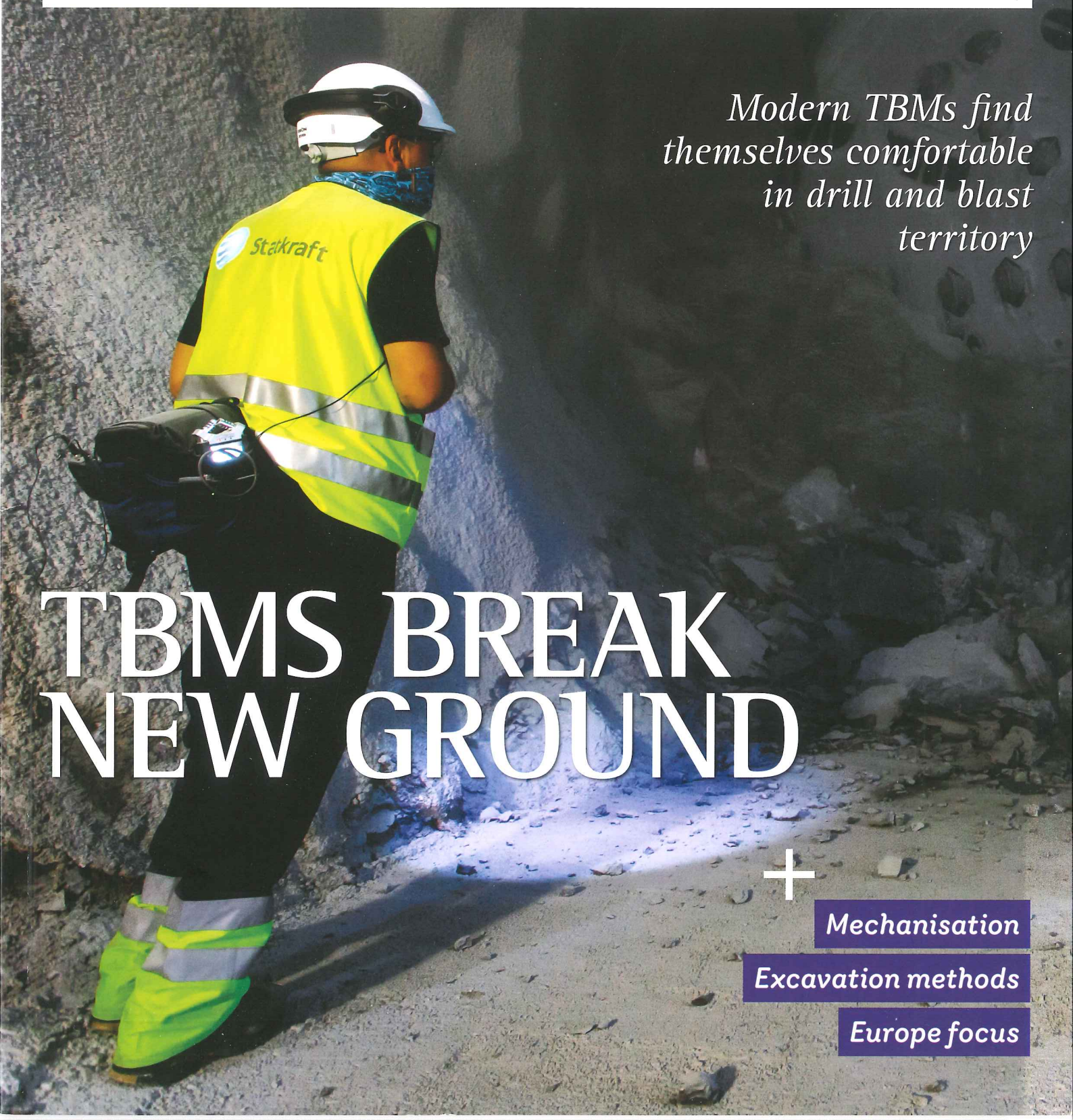
INTERNATIONAL EDITION
April 2015

Tunnels AND TUNNELLING



Modern TBMs find themselves comfortable in drill and blast territory

TBMS BREAK NEW GROUND

+

Mechanisation

Excavation methods

Europe focus

LEE KUAN YEW

LEE KUAN YEW is dead. The direct influence of the man who led Singapore for decades has ended. And many are saying that the driving force behind Singapore's current sway is gone. The tunnelling industry has lost one of its staunchest allies.

Singapore has always been important. Ancient Greek and Chinese scholars wrote about the "island at the end". Then later the Portuguese, Dutch, and the British regularly fought for this vital hub in the Asia Pacific region. The Battle for Singapore between the British and Japanese in 1942 was called the worst military defeat in the history of the British Empire. The shock of the loss of Singapore marked the beginning of the end for the British in Asia.

Throughout the reign of LKY, as he is affectionately known, Singapore has seen independence, followed by a relatively short merger with Malaysia, then independence again. He oversw the neglected port town turn into a corporate haven.

Speaking in 2007 of Singapore's lack of natural resources, LKY said, "We knew that if we were just like our neighbours, we would die. We knew we had nothing to offer against what they had to offer. So we had to [be] different and better."

He was referring to his promise in the 1960's that he would set up a centre of meritocracy, and allow success to thrive without hindrance. It worked. Although some of his stern methods have been questioned. The global media has over-remarked on the restrictions he placed on journalism, for example. One of my early site visits was ended due to a dispute between the Singaporean Military and a subcontractor over seawater corrosion to machinery and tools. Tunnels and Tunnelling has previously praised the regime's efficiency at implementing infrastructure projects.

We remarked in the May 2011 Editor's Comment that the UK was voting on the system by which votes are tabulated in order elect the government. And also, whether the people of the country should even have a say over technical matters that the majority of them will vaguely understand at best. Or to quote the comment directly, "Democracy is a commodity that should be limited, in both the issues it is applied to, and the people allowed to participate".

In 2011 we wrote that the Alaskan Way Viaduct Replacement Scheme narrowly avoided an aggressive campaign to kill it despite the contracts already being let. Now due to the delays to the project, it is being lampooned in US media. Viaducts are ugly, and detrimental to the local community.

This particular example is also at risk from seismic activity. And yet members of the public are calling for the tunnel's cancellation even now.

In Switzerland, voters are given extensive referendum privileges. However, after voting favourably for a crucial new Lake Geneva crossing, they have since rejected both tunnel and bridge options.

This is not to say there should not be discussion around the scope of a project. But it should be competent. When developing its transport masterplan, the Singaporean government charged two departments with the job: the Land Transport Authority (LTA) and the Urban Development Authority (UDA).

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

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

Alex Conacher
Editor

Cover
The font cover shows a miner of the Kargi hydel project as Lok Home of Robbins argues the case for TBMs

Next issue
In the next issue of Tunnels and Tunnelling we focus on North America in the World Tunnel Congrss issue. The tunnelling industry heads to Dubrovnik in a key event in the history of tunnelling. The ITA is being shaken up with a young members group.

This month...

20 YEARS AGO
To realise its plans to construct the USD 2bn Niagara River Hydroelectric Development, Ontario Hydro will drive a pair of 10.5km long, 12.5m i.d. diversion tunnels under the feet of millions of tourists. Along most of their length these twin tunnels, which will increase diversion capability by 55 per cent, will follow the corridor of the exisiting Sir Adam Beck facilities passing under the City of Niagara. About 90 per cent of each tunnel will be constructed within the Queenston Shale formation. Sloped sections at the intake (1.2km) and outake (1.5km) ends will pass through the overlying dolomite, limestone and shale. Mucking will be through the outlet portal.
Tunnels and Tunnelling, April 1995, p.9

30 YEARS AGO
Bids for three more tunnelling contracts and four more shaft sinking contracts are to be opened during April and May to get the bulk of the extensive Milwaukee interceptor sewer project under construction. The largest of the tunnelling contracts is the 30ft (9m) diameter, 28,600ft (8.7km) long bore. All tunnels will be driven through hard rock some 300ft (91m) below the streets of Milwaukee and are expected to be excavated by full face TBMs. The need for such an elaborate scheme is to improve the water quality of the Great Lakes. Most of Milwaukee's sewerage system is a combined scheme, with stormwater and sewage transported in the same sewers.
Tunnels and Tunnelling, April 1985, p.9

Left: The Brenner Base Tunnel will be 64km long when the railway project through the Alps is complete, page 35

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

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Adrian is a former editor of *Tunnels and Tunnelling* and a regular contributor.

Atkins to provide HS2 BIM services

GREAT BRITAIN — Atkins has won a four-year contract to provide BIM technical services to HS2, the company behind Britain's new north-south rail link.

The contract will include professional support covering the planning and delivery of a range of activities including BIM educational and assessment tools for the supply chain, and working to help drive long-term efficiency and durability into asset management.

Last year HS2 published the findings of a study looking at BIM readiness within the supply chain. It found an ever-increasing awareness and implementation, but also some inconsistency in the way firms approached up-skilling and need to improve benchmarking against client expectations.

Since then, work has been underway to develop an approach together with the BIM Taskforce, to help build digital skills and know-how across thousands of suppliers to the UK's design, construction and civil engineering industries.

BIM Level 2 - which aims to create a common data environment throughout the supply chain - will be mandated on all major government projects by 2016.

Jon Kerbey, HS2 director of BIM, said: "I am very pleased that Atkins are on board to help us achieve our vision of delivering a world-class implementation of BIM. HS2 is one of the largest infrastructure projects in Europe and a fantastic opportunity to embed BIM right from day one, delivering real value to the project - and to the industry as a whole."

Mark Roberts, director of Atkins, said: "Adoption of BIM will revolutionise programmes like High Speed 2, materially improving delivery efficiency and success, and embedding an approach that looks beyond design and construction into the requirements and benefits for the whole operational life of the railway.

"We are delighted to have been chosen to work alongside our HS2 and supply chain colleagues to implement a BIM approach that we believe will be ground breaking, deliver great success and ultimately help support the UK's economic prosperity."

News briefs

HONG KONG

The Leighton Asia-LNS JV that has been working on the HATS Stage 2 project for over four years, has marked the substantial completion of HATS this month. The HATS Stage 2 project improves the water quality of Victoria Harbour, Hong Kong, by transferring the sewage to a sewage treatment facility through the subsea sewage conveyance system from Aberdeen to Sai Ying Pun. The Leighton Asia-LNS JV team said it was proud of the accomplishment.

AUSTRIA

The Gemeinschaftkraftwerk Inn (GKI) power station tunnel in Austria (contractor Hochtief) will use conveyor technology outside the tunnel, and rail track mucking inside for mucking. The outside conveyors are to be shipped and installed by Agir, with installation to be complete by August. The pressure tunnel with a total length of 22.6km and a diameter of 6.5m will run underground from the reservoir in Ovella to the powerhouse in Prutz. The value is around EUR 130M (USD 143M).

CENERI WEST TUBE BREAKTHROUGH

SWITZERLAND — After one final blast, at exactly 12:00 on 17 March, the miners in the Ceneri Base Tunnel could shake hands. Thirteen months ahead of schedule, the first breakthrough to the south took place in the west tube of the Ceneri Base Tunnel. The final breakthrough to the north is planned for the beginning of 2016. The Ceneri Base Tunnel will become operational at the end of 2019.

Renzo Simoni, CEO of AlpTransit Gotthard, spoke of his great pleasure at the efficient progress on construction and expressed his thanks to everyone involved, especially the miners. "This first breakthrough in the Ceneri Base Tunnel is a further important milestone in the construction of the New Rail Link through the Alps. Only with the 15.4km-long base tunnel under Monte Ceneri will the continuous flat route from Altdorf to Lugano become reality."

Around 400m away from the south portal at Vezia, in the presence of the director of construction of the Canton of Ticino, Claudio Zali, more than 600 miners and project participants followed the first breakthrough of the Ceneri Base Tunnel. In the southbound west tube, breakthrough took place with great accuracy: at two centimetres horizontally and one centimetre vertically, the deviation was extremely small.

Breakthrough in the southbound east tube was scheduled for the end of March as *T&T* went to press.

Driving in the northbound tubes is still progressing at full speed. Until the breakthrough point at Vigana, the distance remaining to be excavated in the west tube is around 1,500m and in the east tube around 2,000m. Final breakthrough of the Ceneri Base Tunnel will take place at the beginning of 2016. And according to Simoni, there is no change in the previously planned date for opening of the Ceneri Base Tunnel in December 2019: "AlpTransit Gotthard has every intention of achieving this goal."

MTR appoints Leong as chief executive officer

HONG KONG — Mass Transit Railway (MTR) has announced a new CEO. Acting CEO Lincoln Leong Kwok-kuen took charge on 16 March for a term of three years.

"Having been a key member of the MTR Executive Directorate since 2002, Lincoln has good appreciation of the Corporation's strengths and areas where it can become better," said Raymond Ch'ien, MTR chairman.

"He also has the skill to steer MTR to achieve its strategic objectives.

"As acting CEO since August of last year, Lincoln has led the company through a number of important milestones, including the opening of the Island Line Extension to Western District last December."

Aged 54, Kwok-kuen obtained a Bachelor of Arts, and then a Master of Arts from the University of Cambridge in the UK in 1982 and qualified as a chartered accountant in the UK in 1985 and Canada in 1986.

Kwok-kuen joined the Corporation in February 2002 as finance director.

In May 2008, his scope was expanded to cover China and International Business, and his position was changed to finance and business development director.

In July 2012, he became deputy CEO taking primary responsibility in realising the Corporation's growth strategy in the Mainland of China and overseas and head various strategic initiatives.

Since 16 August 2014, Kwok-kuen has been leading the MTR Corporation as acting CEO.

SEATTLE LRT TBM MAKES MILESTONE

USA — Sound Transit tunnelling contractors reached the wall of the future Roosevelt light rail station on March 18, exposing a small section of the boring machine cutterhead and completing the first 1.5-mile (2.4km) segment of a 4.3-mile (6.9km) tunnel that will serve light rail trains from Northgate Mall to the University of Washington starting in 2021.

"This machine churned through hundreds of thousands of cubic yards of earth to reach Roosevelt Station," said Sound Transit Board Chair and King County Executive Dow Constantine. "Now on to the U-District Station, and then to Husky Stadium."

The tunnel work completed by the TBM is the first of six drives being mined as part of the Northgate Link light rail expansion. The machine launched last July from the Maple Leaf Portal at NE 92nd Street just east of Interstate 5 and south of Northgate Mall.

Once it finishes boring through the station wall at Roosevelt, it will undergo maintenance at the site before continuing south and connecting later with the completed University of Washington Station, which opens with University Link early next year.

These tunnels are being constructed by the same contractors, Jay Dee Contractors of Livonia, Michigan, Frank Coluccio Construction Company of Seattle, and Michaels Corporation of Brownsville, Wisconsin, that successfully completed two one-mile tunnels for the University Link light rail project.

A second machine launched from the Maple Leaf Portal last November. It is expected to arrive at the Roosevelt site this summer. Both tunnels are expected to be complete by mid-2016. Cross-passages and tunnel finishes are scheduled for completion in early 2018. When service starts in 2021, light rail trains will enter and exit the tunnels at the Maple Leaf Portal.

Each TBM is more than 300ft long including the trailing gear, and the cutterheads are 21.5ft (6.5m) in diameter. By the time tunneling is finished, a total of more than 500,000 cubic yards of soil will have been excavated and over 7,200 concrete rings used to line the tunnels.

When complete, the USD 2.1bn Northgate Link Extension will connect the University of Washington Station at Husky Stadium to underground stations in the U District and Roosevelt neighborhood, and to an elevated station at Northgate. The extension from Northgate will provide riders with a 47-minute ride to Sea-Tac Airport.

Keller wins Koralm Base Tunnel ground engineering contract

AUSTRIA — UK-based ground engineering specialist Keller has received an EUR 31.2M (USD 3338M) contract for work on the Koralm Base Tunnel link between Graz and Klagenfurt in Austria.

Under the two-year contract, Keller will be responsible for jet grouting, bored piling and anchor works.

The works will be part of the soil preparation activities for the final leg of the tunnel – the KAT 3 contract – which is to be excavated by contractor Porr. Keller expects to start work in the second quarter of 2015.

Keller chief executive officer Justin Atkinson said: "This contract win, which involves a number of different products and requires significant specialist skills, is a testament to Keller's business and performance in Austria."

The Koralm railway line is part of the 2,400km trans-European Baltic-Adriatic Corridor that stretches from Gdansk and Gdynia on the northern coast of Poland to Bologna and Ravenna in northern Italy.

This high-speed rail project, which is estimated to cost EUR 11bn (USD 11.9bn), includes 130km of double-track electrified line, 12 stations and a 32.9km-long tunnel.

The Koralm line will run between Klagenfurt and Graz, the respective capital cities of Austrian states of Carinthia and Styria, and is expected to reduce the travel time between the cities from three hours to less than an hour. The line is expected to be fully operational by 2023.

The Koralm Base Tunnel project is also featured on page 26 of this issue. Adrian Greeman reports from site.

Seattle LRT TBM operator's cabin

Northern Line TBMs ordered from NFM Technologies

GREAT BRITAIN — The contract to manufacture the Northern Line Extension TBMs has been awarded. London Underground (LU) announced this month that the contract had been awarded to NFM Technologies.

Ferrovial Agroman Laing O'Rourke Joint Venture (FLO), who LU contracted to design and build the Northern line extension last year, plans to launch the TBMs in summer 2016, when the 6m-diameter machines will begin their seven month 2.5km journey from Battersea to Kennington.

Two new stations will be constructed – one at the heart of the Battersea Power Station redevelopment and another at Nine Elms to the east, serving new developments such as the US Embassy and the redevelopment of New Covent Garden Market, as well as existing communities.

Mike Brown MVO, managing director of London Underground, said: "The award of this contract is a key milestone in the extension of the Northern line.

"We are well on track for the tunnelling work to commence next year and, once it's complete, this vital addition to the Underground network will help develop the Vauxhall, Nine Elms and Battersea areas, supporting some 24,000 new job opportunities and over 18,000 new homes. Customers in Battersea and Nine Elms will also benefit from quicker journey times, with the West End and the City being just under 15 minutes away."

The cost of the Northern Line Extension is expected to be up to GBP 1bn (USD 1.5bn), which is being funded entirely through contributions from the developments in the area, which will benefit from the increased connectivity.

Worker killed on KL MRT

MALAYSIA — One worker died while another was injured in an accident at the Semantan Portal Mass Rapid Transit (MRT) construction site last month. A spokesman said the incident involved three Bangladeshi workers.

"One of the workers, identified as Rijaul Abdul Goni, 40, died on the spot. Another identified as Shanaullah, 37, was injured and has been sent to the Kuala Lumpur Hospital.

"The third person identified as Rozlu Karim escaped injury," the spokesman said.

The workers were assembling a steel cage, when the ties that held the steel bars snapped, causing it to collapse on the workers. When asked about the weight of a single steel bar by local media, the spokesman said each bar weighs about 70kg.

Investigations have commenced to determine the cause of the accident. Work has been suspended at the V4 Semantan Portal interface site until further notice.

Construction trains crash on Gotthard approach

SWITZERLAND — The Two construction trains crashed on the train line that leads to the Gotthard tunnel from Lucerne, resulting in injuries and one death, according to local media sources.

At around 5am on 18 March, two trains carrying construction equipment collided on the stretch between Immensee and Arth-Goldau. The trains derailed when they crashed at a switch in the track.

As a result, Swiss Federal Railways has completely shut down the train line that takes passengers through the Gotthard tunnel via Lucerne. Passengers wishing to travel to Ticino from northern Switzerland must travel via Zurich until it has been reopened. The person who died in the crash was a 54-year-old German citizen. He was standing on an outside platform on one of the trains when the crash occurred. Six other workers were inside the train at the time of the crash, and one of them, a 51-year-old Portuguese man, was injured and hospitalised.

Police and firefighters set up a spill prevention perimeter on Lake Zug, which runs next to the affected train track, since diesel and hydraulic oil leaked from the trains following the crash.

The cause of the crash remains unknown. An inquiry has been launched by the canton Schwyz public prosecutor and the Swiss Safety Investigation Service, together with local police.

Crossrail TBM arrives at Liverpool Street

GREAT BRITAIN — TBM Victoria, named after Queen Victoria who oversaw the birth of modern railways, has broken in to the eastern end of the Liverpool Street Crossrail station this month. The breakthrough, 40m beneath London, is part of Crossrail's longest tunnel drive, 8.3km.

Victoria now has 750m of tunnel to bore, before arriving at her final destination at Farringdon station this spring.

Victoria has joined her sister machine, Elizabeth, at Liverpool Street who arrived in January and will shortly begin her journey to Farringdon. Elizabeth's arrival will link all Crossrail tunnels for the first time with the big east/west breakthrough at Farringdon in the spring. A Dragados/Sisk JV is constructing the eastern tunnels between Pudding Mill Lane and Stepney Green, Limmo Peninsula and Farringdon, and Victoria Dock Portal and Limmo.

The station tunnels at Liverpool Street have been built by a joint venture comprising Balfour Beatty, BeMo Tunnelling, Morgan Sindall and Vinci Construction.

DELHI METRO CORP SEES IMPRESSIVE TBM NUMBERS

INDIA — A total of 19 TBMs are simultaneously engaged in constructing tunnels across Delhi. It is one of the largest tunnelling projects ever undertaken.

As part of its third phase of expansion, Delhi Metro is constructing more than 53km of underground Metro lines comprising of 74 different tunnelling drives of about 37km. Some 35 TBMs are to be used for this mammoth assignment during the entire third phase and about 21km of tunnels (or 41km of tunnels including up and down tunnels) and 33 tunnelling drives have already been completed so far. The entire tunnelling work of Phase 3 is expected to be finished by the end of 2015.

The use of 19 TBMs simultaneously within the confines of one city is among the highest used anywhere in the world. In Phase 2, Delhi Metro had used a total of 14 TBMs during the entire span of work.

For the current phase, so many TBMs are being used because the proportion of underground construction has increased significantly compared to the last two phases. While, Delhi Metro currently has an operational underground section of approximately 47km, the third phase alone will alone have more than 37km underground.

Work on Phase III will require some 25 TBMs in total. In Delhi, the decision to go underground is purely a financial one, with overhead lines preferred where possible.

Table 1. Location of Delhi Metro TBMs

Phase 3 corridor	Location of TBM	No. of TBMs
Central Secretariat – Kashmere Gate	Kashmere Gate to Lal Quila	1
	Jama Masjid to Delhi Gate	1
Majlish Park – Shiv Vihar	Azadpur to Mukund-pur	2
	Delhi Cantt. to Naraina	1
	Bhikaji Cama Place to Sarojini Nagar	2
	South Extension to Lajpat Nagar	2
Janakpuri West – Botanical Garden	Dasrathpuri to Dabri Mor	2
	Terminal 1 – IGI Airport to Shankar Vihar	2
	Munirka to RK Puram	2
	IIT – Hauz Khas	1
	Hauz Khas – Panchsheel Park	2
	Kalkaji Mandir – Nehru Enclave	1

Source: DMRC

WESTERN POWERS FLOCK TO NEW ASIAN INVESTMENT BANK

GLOBAL — The new Asian Infrastructure Investment Bank (AIIB) has drawn several western countries into its fold. The China-led venture is an international financial institution that aims to marry Asia's vast financial reserves with its dire need for ever-higher infrastructure funding. The startup capital is USD 50bn.

Politically, it is also a good device for Chinese diplomatic efforts to increase its 'soft power', or general influence. As a result, the US initially indicated its displeasure in a rare attack on the UK, the first western nation to voice its support for the venture, but has indicated regret over its remarks since Germany, France Italy, Australia, and New Zealand have also lined up to join in the weeks since.

The US, which generally dominates the financial markets, claimed to be concerned that existing 'high financial standards' might not be met by the new entity. However, it is widely believed that the US often tries to "hem China in" on the world stage, as financial magazine *The Economist* puts it.

The AIIB, the idea for which was confirmed in October 2014, also has the backing of India and 20 or so Asian countries. It is seen as a rival to the US-dominated 'World Bank', the Japanese 'Asian Development Bank', and the International Monetary Fund (IMF), which is largely dominated by Europeans.

The Economist again points out that Chinese efforts to expand the existing financial institutions with its financial might, and in turn leverage more control, have been repeatedly delayed by the US Congress.

Countries had until 31 March to decide whether to seek membership of the AIIB. In keeping with European enthusiasm for the project, IMF chief Christine Lagarde has said she would be "delighted" to work with the AIIB and saw "massive room" for cooperation.

Christine Lagarde has welcomed the AIIB FREDERIC LEGRAND / SHUTTERSTOCK.COM

International Tunnelling Association launches awards

GLOBAL — The International Tunnelling Association (ITA) has launched its own independent awards. Starting this year, the first ceremony will be held in the Hagerbach Test Gallery in Switzerland. It will include a conference and banquet, registration for which will open in July 2015.

An ITA spokesman said, "With the growth of infrastructure needs and the requirement for better use of space and resources, the development of underground options has often produced effective solutions to these challenges.

"As part of this endeavour, the ITA has taken the initiative to launch its own dedicated Tunnelling Awards to recognise outstanding achievements in the field of tunnelling and underground space use, and provide international recognition to these remarkable contributions."

The ITA announced that it had identified nine categories of awards for which candidates can register online. The categories cover projects of various sizes, as well as technical, environmental and safety initiatives put into place.

Website submissions will be possible between 10 April and 14 August at awards.ita-aites.org.

Singaporean Prime Minister Lee Kuan Yew dies aged 91

SINGAPORE — The prime minister of Singapore has died. Lee Kuan Yew passed away at the age of 91 last month. Lee was a forceful politician, and much of Singapore's decisiveness in planning infrastructure engineering projects can be argued to stem from him.

As the city-state's prime minister for 31 years, he was widely respected as the engineer of Singapore's prosperity. Under him, a small port city, albeit in a strategic location, was transformed into a global financial centre.

He also oversaw Singapore granted independence from Britain, and separation from a relatively short-lived union with Malaysia.

Key to the city-state's current level of prosperity and business is the transportation network which allows such a dense collection of foreign and local businesses to work effectively on such a small amount of land.

US President Barack Obama described him as a "giant of history". The Chinese foreign ministry called him "a uniquely influential statesman in Asia". UN Secretary General Ban Ki-moon Tweeted that he was deeply saddened by Lee's death.

A charismatic figure, Lee co-founded the People's Action Party (PAP), which has governed Singapore since 1959, and was its first prime minister. In 1965, he pledged to build a meritocratic, multi-racial nation. But tiny Singapore – with no natural resources – needed a new economic model.

OLDEST RAIL TUNNEL PROTECTED

GREAT BRITAIN — The world's oldest railway tunnel has been given protected status. Fritchley Tunnel, which dates from 1793, was built as part of the Butterley Gangroad, a horse-operated railway linking the Cromford Canal with quarries at Crich. The Derbyshire tunnel has been scheduled as an ancient monument.

Sealed up in the 1980s, the tunnel was excavated by archaeologists in 2013. It was engineered by Benjamin Outram, and was modernised in the 1840s to accommodate a narrow gauge railway. The line continued to be used by steam engines until 1933.

Tony Calladine, from English Heritage, said Outram was "an important figure who greatly influenced the development of railways in Derbyshire and across England".

"He was one of the first to recognise the potential of railways to provide a nationwide transport system which would bind the country together and the Butterley Gangroad was where he first developed the ideas which were soon adopted across Britain," he said.

Crawshaw Woods Bridge was designed by Scottish engineer James Walker.

English Heritage said the bridge, which has been granted Grade II-listed status, was testament to one of the "Victorian's greatest achievements" (railway networks).

A spokesman for English Heritage said: "Railways gave the Industrial Revolution its impetus and staying power, transforming the lives of millions, so this bridge is a key reminder of a momentous period in our country's history."

ATS gives Brisbane River crossing update

AUSTRALIA — The Australasian Tunnelling Society (ATS) has last month published an update on the tribulations of crossing the Brisbane River, as follows:

For the third time in eight years, and with its fourth premier, the Queensland government has to start from scratch to find a new cross river rail line for Brisbane. South East Queensland has a growing rail congestion problem because it has only one rail bridge across the Brisbane River.

In 2007 Peter Beattie unveiled SEQ's Inner City Rail Capacity Study, which clearly said the region needed a new rail bridge by 2016 because the Merivale Rail Bridge could not cope. In 2009 Anna Bligh's government put together the AUD 7bn (USD 5.5bn) cross river rail twin-tunnel project and released the first concepts in 2010. In 2012 Campbell Newman scrapped Labor's Cross River Rail plan and introduced the Brisbane's Bus and Train (BaT) project, a single tunnel concept that included buses and trains underground.

And, now Premier Annastacia Palaszczuk has ditched the BaT Plan, with Infrastructure Minister and Deputy Premier Jackie Trad confirming that model would not go ahead.

"The BaT tunnel was given up when Lawrence Springborg appeared on Fairfax Radio and said asset sales and the BaT tunnel were off the agenda," Trad said.

"What Labor will do is progress a second rail crossing for Brisbane, but we will progress it with the federal government."

She said she had discussed the project with Deputy Prime Minister Warren Truss and would again approach Infrastructure Australia. Infrastructure Australia is the independent infrastructure agency that prioritises large infrastructure projects on behalf of states for the federal government.

In 2013 Infrastructure Australia rated the Cross River Rail project as "ready to proceed", with the then Queensland government seeking AUD 3.4bn (USD 2.66bn) for the AUD 4bn project. By mid 2013 no agreement could be reached between the governments in order to get the project off the ground.

"We know that this was the number one public infrastructure project that Infrastructure Australia said needed to be built in order for Brisbane to grow into the future," Trad said. "Labor is committed to continuing to lobby the government to make sure that we can build a second rail crossing to stop the rail crisis that will hit the southeast corner in 2016."

Meanwhile Infrastructure Partnerships Australia chief executive Brendan Lyon said the question would always come back to the money, despite the well-recognised need for the project.

"The Cross River Rail is going from important to urgent given the growth in patronage on Brisbane's rail network and the fact that every train will be full to bursting point in just a few short years," Lyon said. He added that the Queensland government needed to explore a PPP to get the project operating.

"A new rail crossing of Brisbane's river needs to be a top order priority for Queensland, but finding money to pay for it will be hard given the challenging budget and high levels of existing debt," Lyon said.

"While the state would be wise to use a PPP to finance the project, there will still need to be budget capacity to repay the cost over time."

Letter

Rooting for the good guys

Sir,

I must congratulate both Søren Eskesen and your publication for highlighting how underground space can be brought to bear on the battle against climate change and global warming (ITA President sees increased International Awareness, Tunnels and Tunnelling International, February 2015).

It's about time we engineers declared ourselves in this, the biggest challenge faced by humanity since anyone can remember. For too long we have been pussy-footing around, mindful that some of our fees arise from organisations in whose interest agitating to do something about fossil fuels for example, is anathema.

More please.

Yours sincerely,

Simon O'Hana
Associate Principal – Transport and Resources
Arup

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

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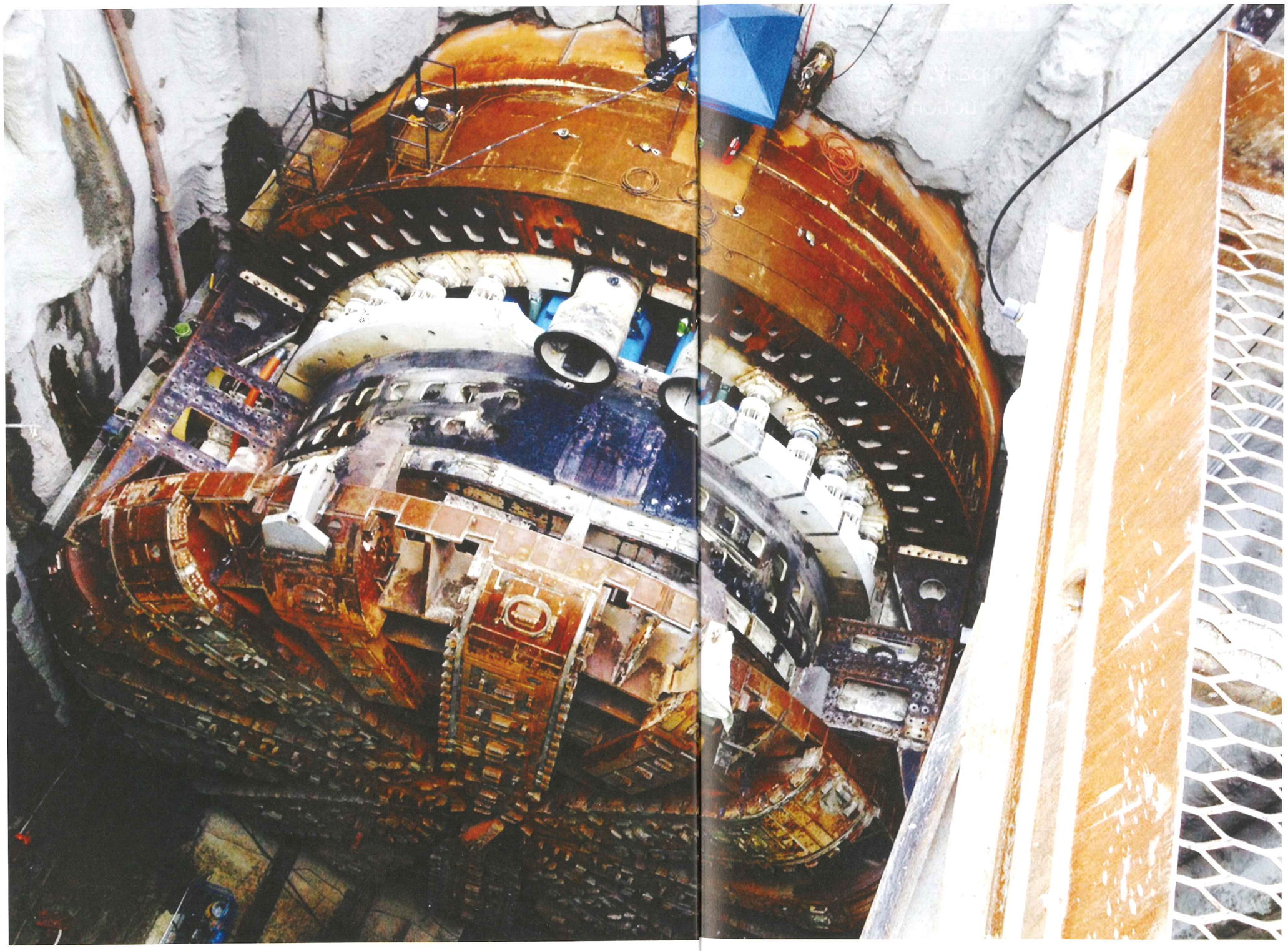


Left: On the Alaskan Way Viaduct Replacement Project two pieces of the front shield have now been lifted from the access pit built to bring the front end of the machine to the surface for repairs. The third piece of the front shield was due to be lifted as Tunnels and Tunnelling went to press.

WAYSS & FREYTAG TUNNEL BOSS ASSESSES MECHANISED IMPACT

The German construction company *Wayss & Freytag* has played a significant role in the development of mechanised tunnelling. Around 50 years ago, the company was involved in the development of the hydroshield technique. The first fully mechanised tunnelling machine was used in the construction of the North-South metro line in Munich in 1966. Since then, *Wayss & Freytag* has completed over 250km of tunnels with diameters up to 14m. **Roland Herr** speaks to tunnelling MD **Klaus Rieker**

What was the most challenging project in your tunnelling career?

Rieker: The most difficult projects are usually those where you notice at a very early stage in construction that design and reality don't coincide; where progress made doesn't come up to expectations; where costs exceed the budget. These projects require a great deal of special attention.

What are the most important developments in mechanised tunnelling?

Rieker: In the past, people tried to build tunnels only where the soil

In 1996 the world's largest TBM is manfuactured to excavate the fourth tube of the Elbe River tunnel. The 14.2m Herrenknecht Mixshield broke through in March 2000

conditions were suitable, i.e. simpler, more predictable. In areas where the soil was consistent and homogenous, a particular type of machine was used for just this type of soil: slurry shields in coarser soils such as gravel; EPBMs in finer soils such as clay or silt; and classic hard rock TBMs.

In the course of the last few years developments in tunnelling have been such that tunnels tend to be needed exactly in those in places where the soil conditions are inconsistent or where cover varies considerably. Because of infrastructure density in congested urban areas for example, tunnels sometimes run very close to each other und thus machines had to be developed to successfully deal not only with more than one type of soil but also with other difficult underlying circumstances.

The development of additives (foams or polymers), has also greatly improved mechanised tunnelling. A far wider spectrum of geological challenges can be successfully dealt with than used to be the case. This has considerably enlarged the field of application. Concurrently there has been a rapid growth in tunnel diameters.

These days, 15m-diameter TBMs are no longer a rarity and are supplied by almost all manufacturers. The standard diameter today is 11m, as this is required for railway tunnels. Larger diameters are usually needed for road tunnels.

Above: In 1985 Herrenknecht works with Wayss & Freytag to produce the first large diameter (6m) Mixshields. This one worked on the 6.2km HERA particle accelerator

Which regions are particularly interesting?

Rieker: In Germany and its neighbouring countries, tunnelling is on the wane. A large number of railway lines which required a large number of tunnels have now been completed. The underground railway lines in Germany, above all in the cities, have been more or less fully developed. The demand for large tunnels in central Europe is therefore on the decline.

In Britain, particularly London, there is still a lot of tunnelling in progress. In future, some projects can also be expected to be realised in Norway or Sweden.

A considerable boom can be observed in Asia. In Singapore for example, 10 to 20 tunnelling machines have been in operation simultaneously for years to extend the underground railway system there. In Thailand, too, a number of projects should be realised, although construction has slowed down considerably in the past year as a result of the political situation. China is an enormous market with a large number of projects, in answer to which Herrenknecht, for example, have established their own local production plant. In India, too, there's a large market for tunnels. In Australia there are still a few projects. In America, mechanised tunnelling is also becoming more and more established. Although we, as Wayss & Freytag, are no longer active on the American market, we did use to work there when Frontier Kemper was part of our group. We continue to follow this market with increasing interest as more and more tunnelling projects are being launched. In my opinion, the future potential there is considerable, above all as the need for diversion tunnels grows in the face of increasing water supply problems.

What does the market look like if one were to divide it according to the type of projects, e.g. road, or water supply tunnels?

Rieker: In South East Asia in particular, a large number of metro lines are being built. In other regions, such as India, a large number of diversion tunnels are being built, particularly in the more mountainous areas.

There is enormous demand for wastewater tunnels, and indeed whole wastewater systems, in large cities. Here the current systems are no longer sufficient and in some countries, such as in Singapore or in Abu Dhabi, large systems are being built to transport the wastewater to new and larger treatment plants. In the course of this, a market is created where pipe jacking will also play an increasingly important role.

Which are the most important manufacturers/suppliers of tunnelling machines?

Rieker: Herrenknecht is, without a doubt, the most important supplier of slurry shields; for hard rock shields Robbins must also be mentioned and NFM has recently become more interesting for EPB shields. This is not a judgement, however, as all suppliers offer machines for nearly all types of soil. Lovat, the Canadian company, used to have a name for EPB shields.

In Europe, and also in the Near East and America, the aforementioned three suppliers are market leaders, although Herrenknecht certainly stands out as far as the number of machines sold is concerned.

In Asia there is also Hitachi, Kawasaki, Mitsubishi, STEC or CREG, but these suppliers produce shields for standard applications. In Australia there is Terratec.

Above: Klaus Rieker of Wayss & Freytag has extensive experience in mechanised tunnelling

What would the perfect tunnelling machine look like?

Rieker: A tunnelling machine must be perfectly suited to the prevailing soil conditions. There is therefore no such thing as the perfect machine for all types of soil. A tunnelling machine is a machine built bespoke for a given project, the local soil conditions and the required diameter. For example, not all underground railway tunnels are constructed with the same diameter. In fact, sometimes diameters vary within one town, be it only by 50 or 100mm. At the end of the project the tunnelling machine must have paid its way. Usually it is returned to the supplier who will at times take great pains to refurbish it so that it can be used again as a second hand machine at a considerably lower cost.

So there is a market for second hand machines?

Rieker: These days all machine suppliers use second hand or refurbished components from time to time and offer second hand machines. There is nothing to be said against using the electric or hydraulic components and drive assembly of a machine more than

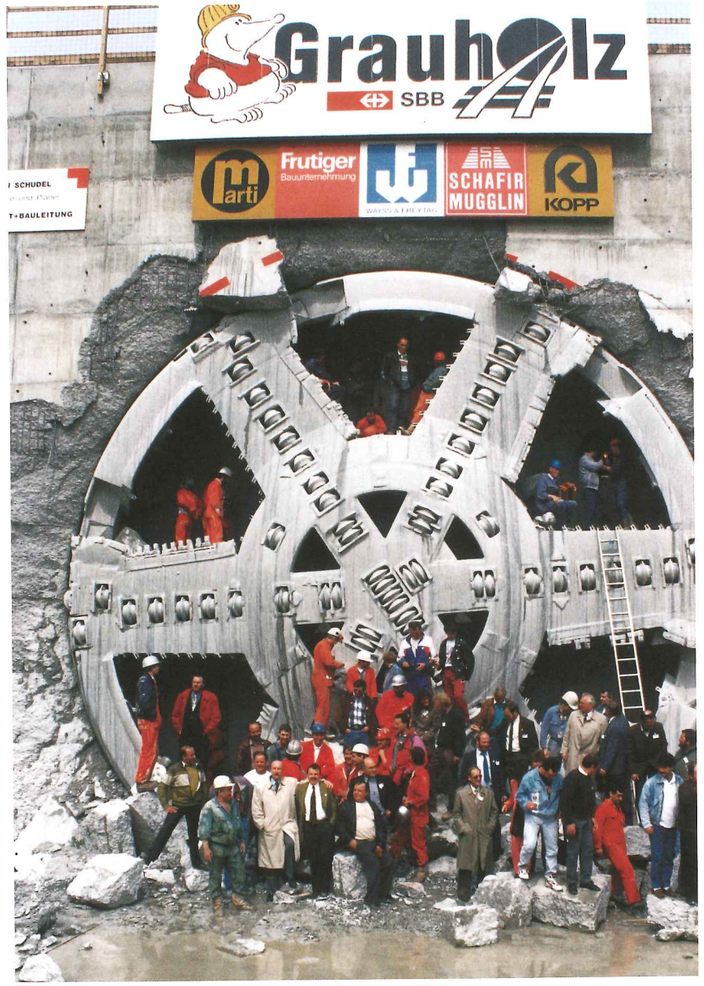
once, above all when the previous tunnel drive was a short one. Such components are refurbished by the manufacturer or supplier so that they are to all intents and purposes as good as new and then reused. The manufacturer even supplies a warranty for these used parts.

The large manufacturers Herrenknecht and Robbins each have a different philosophy regarding the assembly of a TBM.

Yes, Herrenknecht design the tunnelling machine and assemble and test it at their plant. Then, the machine is partially dismantled and re-assembled on site. Robbins, on the other hand, also offers the assembly and testing of the whole tunnelling machine directly on site. This approach is generally thought to be more economical. I personally prefer the machine to be assembled and tested at the plant. With the aid of today's modern design methods and 3D-drawings it is, of course, much easier to conceive, design and build tunnelling machines. Nevertheless, it does happen that parts have to be adapted during assembly. This can certainly be done much more easily and quickly under controlled conditions at the plant than subsequently on site. Should something not fit, it may well be that this has to be delegated or transported back to the plant to be dealt with.

If the machine is constructed and handed over at the plant, then loaded, transported and re-assembled on site everything is relatively clearly defined and documented according to a tight timeline. If the initial assembly is carried out on site, the time required for assembly at the plant is saved, but you never know whether the time foreseen for assembly on site is sufficient.

On some projects the construction of the tunnelling machine is not necessarily on the critical path. Once the contract has been awarded, the machine has to be ordered. At the same time, if the tunnel has a segmental lining, the segments must be designed, the formwork ordered and, in some cases, the segment works erected and the segments produced. An approach ramp or cavern or a start shaft is often needed as well. Experience shows that the time required for all this is often as long as it takes for the machine to be assembled at the plant, dismantled and delivered to the site. In my opinion, the time advantage offered by initially assembling the tunnelling machine on site is not the decisive factor. However, it may be that for hard rock machines, it could be an advantage, as they do not require segments and therefore can dispense with the necessary infrastructure.



Above: In 1988, the Mixshield surpasses the 10m mark with this 11.6m machine destined to excavate the Grauholz Tunnel in Switzerland

What is the decisive factor when choosing a supplier?

Rieker: That fully depends on the underlying ground conditions. Where hard rock machines are concerned Robbins is certainly a known entity.

I wouldn't hesitate to use a Robbins machine to drive a tunnel through hard rock, as long as the technical requirements are met and this is also the most economical solution.

Wayss & Freytag, however, has made a name for itself in tunnelling in loose rock. Our speciality are slurry shields. This is what we started out with.

Later, we added EPB shields and in the past few years we also work increasingly in hard rock. In those countries on which Wayss & Freytag has focussed and successfullly carried out projects in the past such as Germany, Switzerland, Austria, the Benelux countries and Britain, the prevailing soil conditions require mainly slurry and EPB shields.

Furthermore, until a few years ago, hard rock machines were hardly used in the Alps, as the drill and blast method was preferred. In order for a hard rock machine to be competitive with drill and blast, the tunnel must be a certain length; approximately 5km

SECOND BTSYM CONFERENCE HELD

The *British Tunnelling Society Young Members* hosted its lively conference for the second time, and hope to make it a regular event as its popularity swells

THE BRITISH Tunnelling Society Young Members (BTSYM) group held its second conference last month. Following on from the first event in 2012, the popularity of which caught organisers unaware and necessitated an overflow room, this event was held free of charge at the spacious premises of the Pinsent Mason law firm in London.

The programme was also expanded, with talks spanning topics such as feasibility planning, design, case studies, and a session for special topics. In a sense, the 2012 conference appeared to be aimed more at potential tunnel engineers, and while the 2015 conference was also aimed at young people, it felt like it had a more practical leaning.

A particular early highlight for the room was Si Shen's presentation on the Crossrail Two Engineering Feasibility Study. With deadpan humour, he took the audience on a vivid journey through the various feasibility considerations, and creative, value-adding solutions, before sadly telling the room that "now we must return to reality – a world of rules."

Above: The panel during the feasibility session of the conference

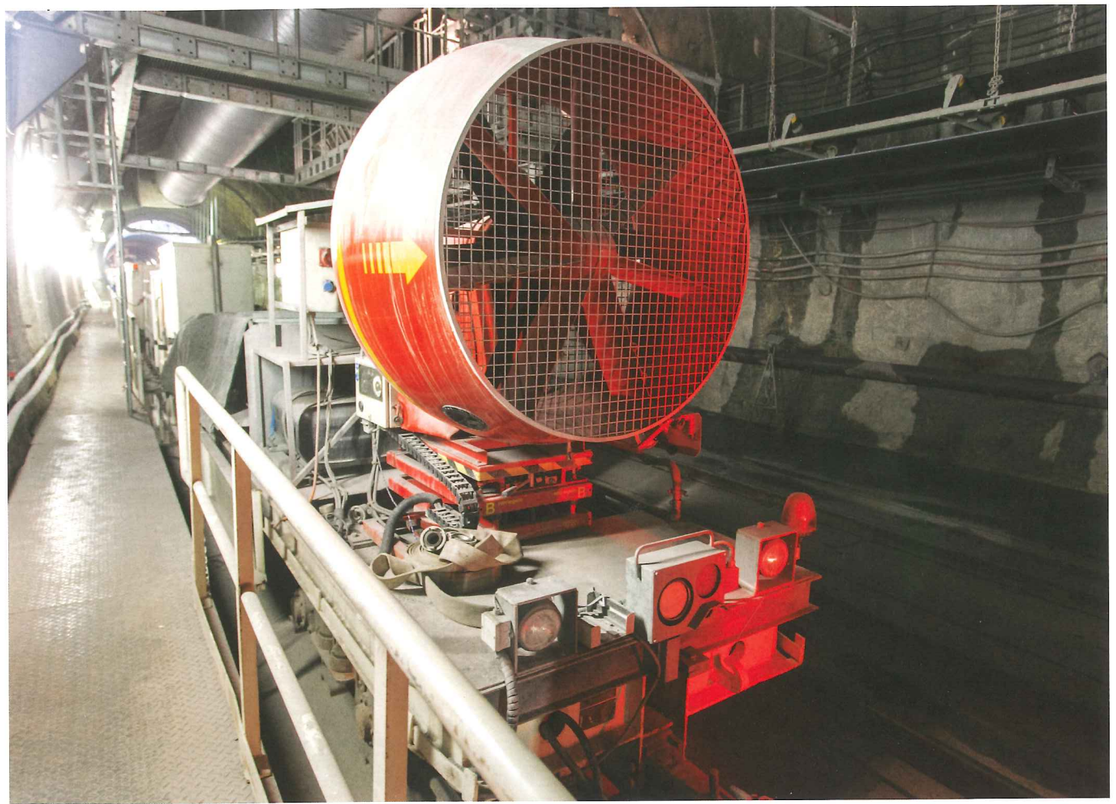
Tunnels and Tunnelling spoke with Eoin O'Murchu, the BTSYM chair after the event to get his views. "I think the conference was a complete success of all fronts. From the venue, the number of attendees, and the high quality of presentations, it went as well as we could have imagined.

"The aim of the conference was to highlight all aspects of tunnel design – from conception to completion – and I think that was achieved quite well. Although my own particular highlight was the number of new faces in the crowd.

He added that, "The key aim of the conference was to afford young tunnelling professionals the opportunity to present aspects of their works to their industry colleagues. I feel everyone in attendance gained a greater insight into what their counterparts in the industry do and how they do it. The networking aspect of the day was also critical to its success.

The BTSYM announced that the plan is to hold another conference in 2016, and with Pinsent Mason's permission they hope for the same venue. O'Murchu concluded, "I think there is no reason we should not make this a regular event as the demand and talent for great presentations are clearly there.

"The BTSYM is very grateful to [BTS chairman] Roger Bridge and the BTS main committee for all the support they gave us in organising the conference this year"



KORALM CATCH UP

The 32.8km Koralm high speed rail tunnel in southern Austria will be one of Europe's longest; one of three base tunnels now underway in the country

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

IT HAS been tough going for the long hard rock drives on the central contract for the Koralm high speed rail tunnel in Austria. Blocky unstable rock conditions have slowed progress for the two Wirth TBMs making the approximately 17km long main bores and daily averages have been only just over half the hoped for daily rates of 25m.

The drives, are about halfway through at present, about 10km into their final lengths which are slightly different on the north and south drives at 17.2km and 16.2km. Client, Austria's Federal Railways civil engineering company ÖBB Infrastruktur, has said that things are within the parameters of the contract for the eventual 2018 completion. Another contract has yet to be let for a final 10km of the tunnel, which will be 32.8km in total.

"The machines are very good in fact," says Robert Goliasch, technical equipment manager for the project's joint venture contractor, comprising Austrian firm Strabag and its minority partner Jägerbau. They are very strong and actually I would say they are among the best I have seen."

But the igneous rocks of the Koralpe Mountains, situated to the south of the main Alpine ranges, have proved more troublesome than thought, even for these. "It is all gneisses but there are possibly 20 different kinds" says Goliasch "and some of these are very foliated." The different types vary constantly he says with TBM operators always needing to be vigilant to adjust machine settings.

TOUGH GOING

Some of the foliated sections break into very sharp shards under cutter disc pressure he says which is problematic for the spoil conveyors on the machine and for the long conveyors along the tunnel, cutting in to the belts and causing excessive wear and even breaks.

Elsewhere blocky conditions from fracturing have proved exceptionally difficult and have jammed the head on occasion, including one incident where one of the machines became stuck for four months.

"We had to excavate by traditional hand mining methods around the side of the TBM to clear in front of the cutterhead," Goliasch says.

Other sections of the rock have the opposite problem, being very tough and homogeneous. "You can get strengths up to 300MPa and find a single stroke of the machine is taking you three hours to make instead of a normal 35 or 40 minutes," he says. The rock face resists the cutter impact in these areas he says "like a very, very hard rubber you could say, which does not chip easily."

Mixed faces are also difficult with the boundary between rock types causing sudden transitions, which can impact on the cutterheads, sometimes breaking the discs.

All this has faced the contractor in the last two years when it began the second part of its big EUR 570M (USD 625M) contract, the largest of three on the project and comprising some 57 per cent of the overall tunnel.

Work on the project tunnel began with an initial contract by another company, for a short 1.5km long portal section near to the town of Deutschlandsberg at the eastern end of the mountain range. But the major work has been split into two sections, Kat 2, a nearly 20km portion driving from the eastern end and Kat 3, a final 11km section from portals at the western end, was let to Austrian contractor Porr last year. A test tunnel of around 7km has already been completed for that on the southern bore.

Above: The network corridor containing the Koralm project

Opposite: The fan car as described in the fire safety box (page 31)

Below: Aerial view of Koralm construction site

The contractor had some first experience for the shafts from a small exploratory contract done earlier. "We made a smaller shaft, about 13m diameter," says Lehner. That was part of ground investigation works to determine the extent of the softer ground and the boundary with hard crystalline rock making up the mountain range.

With the shafts completed the soft ground work could be done, excavating in two directions, back towards the Kat 1 bores and westwards. The ground was removed primarily with Liebherr 944 tunnelling excavators, with shotcrete and rockbolt support. Mucking out was by diesel dump trucks running to the base of the shafts where crane grabs lifted it away.

Above: A view down a launch shaft showing conveyance

Left: Foliated sections have splintered under cutter disc pressure, causing wear on the conveyors

Below: Graphical representation of the tunnel with east and west portals highlighted

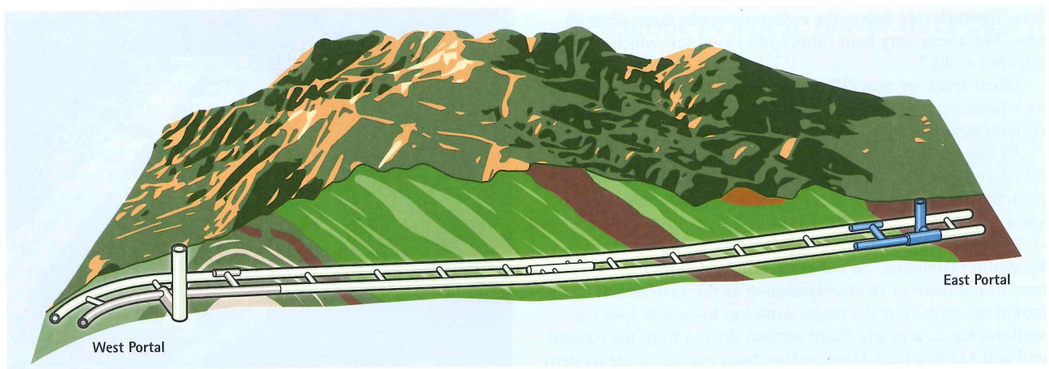
The early went quite well with the tunnels continued to the hard rock boundary about a kilometre past the shafts. At this point two large caverns were excavated in the summer of 2011, ready for the assembly of the TBMs, which are carrying out the main part of the work. The caverns were 40m long, 20m high and 15m wide. The southern drive chamber was begun after other as the clay excavation continued further on this side.

MACHINERY AND LINING

As mentioned the machines selected by the contractor for the main drives are Wirth, which at the time of purchase was owned by Norwegian company Aker, though currently the German TBM maker has been taken over by the China Railway Engineering Group. "But we are still getting good back up," says Goliasch.

Both TBMs are hard rock shield machines as the client has specified that the tunnels be segmentally lined for longevity and durability; for some 30 per cent of the length where rock conditions are most difficult they will also have an inner cast in situ lining as well, to ensure strength and permanence.

"The client is concerned about the tunnel strength long



A significant upgrade

Austrians have long complained about the rail connections across the south of the country. For the tourist visitor the winding train routes through the high mountains are a scenic delight but the journey from Graz to Innsbruck for example can take six hours and other routes are similar.

But the new high speed rail link between the country's third biggest city Graz to Klagenfeld in the east will alleviate some of the difficulties by the end of the decade. Its 124km length will more than half three-hour journey times for passengers, and also reduce freight costs and times.

The central component of the line is the Koralm tunnel a 32.8km long twin bore through the Koralpe mountain range, which though not so high as the Alps themselves is still a major obstacle. The Koralm will be a so-called "base" tunnel therefore with almost flat gradients, achieved by a vertical alignment running up to 1,250m deep below the highest peaks, which are around 2000m high. If not as large as the Gotthard or Brenner Pass connections it will still be one of the largest tunnels in Europe.

The tunnel comprises twin 8.8m internal diameter bores each taking a single track. Cross passages are sited every 500m along the route for safety and maintenance and there will be a central emergency station comprising a series of cross connections into a third smaller central bore. This smaller diameter middle tunnel, 900m long will provide a refuge for passengers who will be rescued from the opposite track.

The new high-speed line will have passenger trains running at 250km/hour, and will also carry major freight traffic. It is part of a much longer transport corridor, the Baltic Adriatic corridor, designated Axis 23 in the European Union's priority transport network, running from Gdansk in Poland to Venice and Bologna in Italy. There are several other major tunnels on the axis including a second long base tunnel, the 27km long Semmering, which is also in Austria to the north of Graz on the line to Vienna. Work began there recently.

Koralm excavation should be finished by 2018. Fit out and commissioning was scheduled for 2020 service.

term in the earlier part of the drives and therefore requires this extra lining," says Lehner. According to discovered rock quality, shorter sections in the remaining tunnel may also have a double lining.

The double lined section will have a waterproofing membrane, and then later on the tunnel will be free drained.

To increase drive performance the machines have a double-shield configuration allowing for continuous driving operation even while the segment rings are being erected at the back. Using side grippers the front part of the shield pushes forwards while the back section is halted for segment erection. They can also be used in standard mode if necessary though of course that is slower.

The TBMs were ordered after a detailed comparison with other options. Location of the TBM manufacturing works was among the factors guiding the choice, the Wirth factory being relatively nearby. "But Wirth, now CREG-Wirth, is also well known for its hard rock experience" says Goliasch.

The two 9.93m diameter TBMs erect a six segment universal ring as they go, 1.9m long and mostly 350mm thick and with an outside diameter of 9.5m.

The ring annulus is backfilled a few rings behind the erector through segment injection points, with a grout for the lowest third of the annulus and the remainder with a blown in pea-gravel.

For the cutterhead Strabag went for 17" discs rather than 19". Goliasch thinks the difference is not so great but the smaller discs have a significant advantage in size and weight which makes them much easier to change when worn or if there are breakages. "The machines have very nice access for removing the discs," he says. Some cutter disc 6,000 changes have been made so far.

The contractor maintains its own disc stockpile and repair workshop on site and refurbishes the disc rings to get about five or six uses from each cutter. It also replaces bearings when needed.

"The cutters are the Wirth type which makes changing the disc rings easier," says Goliasch.

LOGISTICS

Strabag chose a different maker for the back up train using a system from Swiss maker Rowa Tunnelling Logistics. "Our philosophy is not to buy complete systems but to examine and order each component separately," says Goliasch "to get best in class."

Supplies, and personnel carriage, are done using a rail system with Schöma diesel locomotives and segment delivery wagons from Herrenknecht, many of them brought from the work that Strabag did on the Lötschberg tunnel in Switzerland's AlpTransit programme. The rail is double tracked, mounted onto a flat floor in the tunnel formed by a precast invert unit placed into the base of the segment ring. Inverts are cast alongside the segments.

The trains primarily deliver segments to the machines, along with other supplies. Additionally there are five safety trains, one kept ready by each machine and three at the shafts; these proved their worth in a recent fire incident (see box, page 31).

Trains are loaded at the two shafts by big 60t portal cranes from Austrian maker Künz. Anther two 35t cranes also operate in the yard above all controlled by a sophisticated data logging system, which allows for automated "just-in-time" delivery of segments. It is part of a computerised manufacturing and tracking process from VMT being used for the first time on this project for segment casting and storage (see below).

The period of initial soft ground excavation was also used to set up the main mucking out system. This is a complex conveyor network for both the interior of the tunnels, and particularly above ground where spoil is removed to two major storage areas in fields about half a kilometre away. A further storage area sits 1.5km away, also fed by conveyor. Swiss firm Agir is supplying the equipment for the tunnels, the bucket conveyor at the shaft and the above ground network in the storage zone.

The entire conveyor network has a series of elevated belts running in two directions as well as radiating out to assorted storage heaps from a central sieving and sorting plant. This network is needed because of client requirements that as much spoil as possible be re-

used in the project, particularly for the 420,000m³ of concrete needed primarily in production of the segments in the two on site factories. Other material should go to embankments as fill.

Chemical composition of the rock is important for re-use – there can be mica and other minerals making it unsuitable for concrete - and a daily inspection of the rock at the tunnel faces is made to determine which face material goes to the sieving plants and then returns to the batching plants. "There is also a significant fines element which has to be sifted out," says Goliasch.

He says the constant assessment of rock quality and deliveries require a "fine juggling act" by the spoil team.

Some of the material is loaded onto trains which are able to come into the site using a purpose built railway siding connected to the nearby local rail link. It is used for embankments and some goes to disposal sites.

"About 70 per cent of the spoil is for concrete or for such uses," says Goliasch "from a total 2.9Mm³. Some of the material from the tunnels goes directly from the shaft head to the siding if unsuitable for sieving. The remainder from some total will be distributed in the local disposal areas acquired from nearby farms. These will be landscaped later.

The reuse requirements result partly from the client's desire to reduce the work impact on this area of farmland and vineyards, and especially to limit truck movements. It helps that there is a rail link nearby.

Similar environmental requirements have led to the first use of a highly sophisticated segment manufacturing system. Segments are made on site to reduce trucking, but at the same time the site space is highly limited in which to fit the two segment casting factories as well as associated batching plants. Storage areas for finished segments are also tight with just 12,500m² for each factory's output. The yard area for each is 50m wide and extends just 150m back from the shafts, one factory using each side.

"Each can store 550 rings which sounds a lot but would quickly be used during a sustained period of tunnel driving," says segment production manager Andreas Lange. The tunnel will use 17,200 rings, along with their invert pieces.

THE SPICE OF LIFE

Further constraints arise because there must be a greater variety of ring types made than usual. Rings come in three different types, normal, strong, and for cross passage areas additionally reinforced to allow them to be broken through. Each ring has six segments, including two with tapers and a full size key unit, which means a range of segment types and rings.

A complex computerised tagging and tracking system from VMT, the SDS "segment documentation system" has solved the problem. It is used for quality control of individual segments and then for organising their storage in the yard outside.

The system works with a systematised individual bar coding applied to each particular reinforcement cage, to the moulds, and at the batching plant. The code links to a database storing precise details of each.

The finished segment gets a unique barcode too, based on those details. Using hand held code readers the segments are constantly checked and monitored from then on and every detail of their production is stored in a live database.

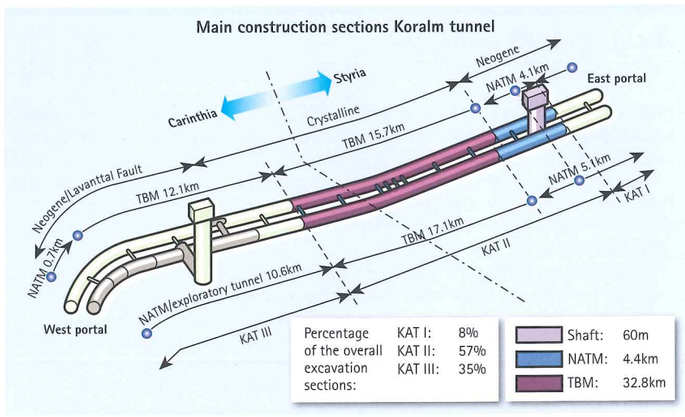
This allows for individual referencing of batching, mould use and laser-scan dimension checking for each segment, but also organises the storage to allow maximum use of the space.

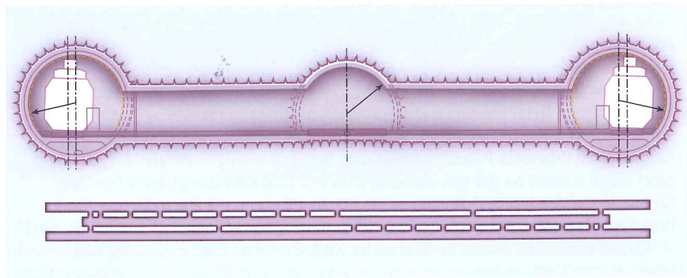
Two rings, each weighing 47.5t can be stacked one on the other in the yard, twelve segments high. Associated large invert units which later fit within the installed rings, weight 13.4t each and are also stacked 12 high.

For production, the cement, additional aggregates, pea gravel filler, additives and steel reinforcement are all delivered by rail wagons, most to silos and buildings alongside the track.

The two segment factories are double level buildings with the reinforcement cages made assembled and welded on an upper floor and then positioned in steel moulds which run on a filling and curing carousel beneath. De-moulding from the Herrenknecht supplied forms after the 8-hour steam curing happens in a short-term closed store, protected from the weather, which can be cold in winter and quite hot in summer. Segments remain for 24 hours before being lifted outside into the storage yard.

"After production only the database system knows where any segment is, filling the spaces in the yard without wasting any places," says Lange. A manual system would mean having different sections of the yard for





Above, top: The project broken down into its stages/contracts

Above: A central emergency station stretches 900m

Below: Segments stacked in the yard during winter

Fire safety masterclass

A fire originating in a generator set put the contractor's tunnel safety arrangements through their paces for real in mid-February. Despite the tunnel being "particularly full that day because of maintenance and client visitors" no one was hurt reports Goliasch. Five miners trapped on the front of the TBM retreated to a sealed safety cabin but were rescued after two hours, and another 20 or so personnel were evacuated with an emergency train. The tunnel radio system worked well says Goliasch.

The train was one of four required in the contract conditions, essentially a fully provisioned sealed refuge cabin with air supplies and protective equipment and a locomotive. "They were made for us by a small German firm Sänger" says Goliasch "and allow for a 12 hour confinement".

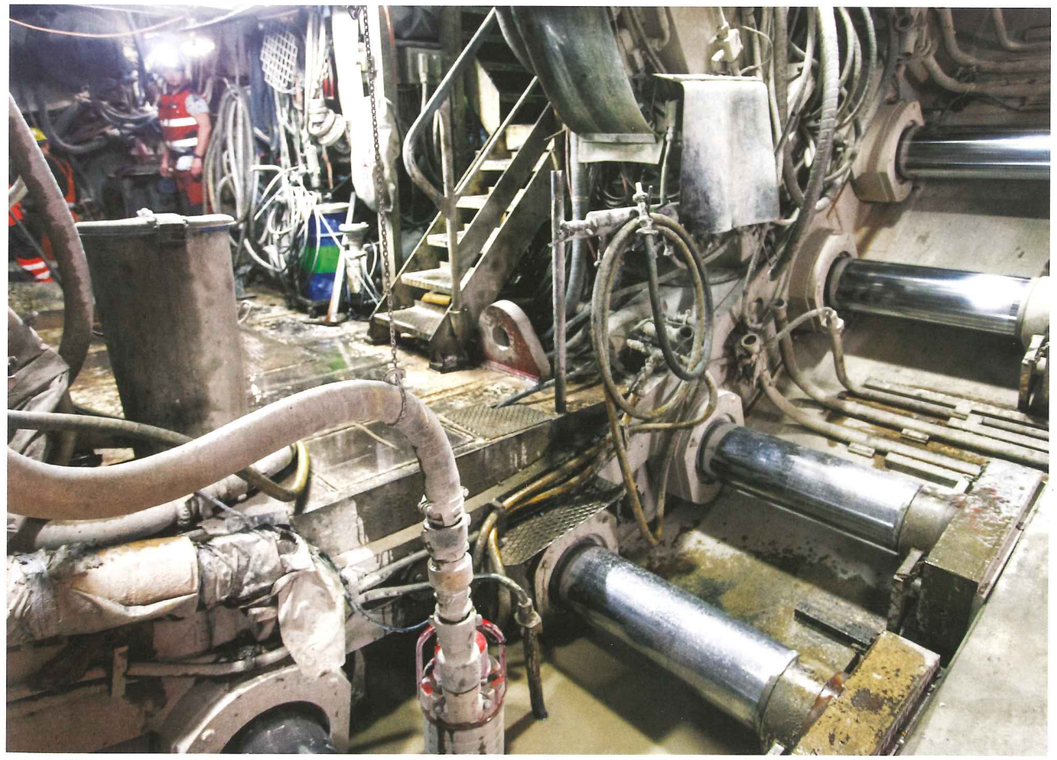
A fifth train is also part of the equipment, designed specifically for fire fighting. It has a large blower unit on the front through which nozzles can inject water to make a fire suppressing spray mist that can be projected 50m along the tunnel.

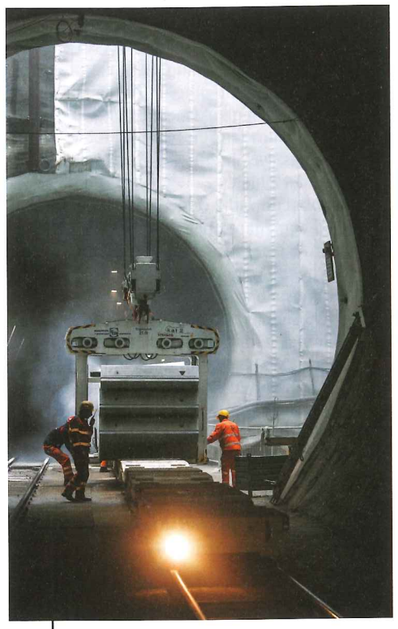
"It carries a large water tank for the first few minutes and then can be connected to water lines along the tunnel to pump more water" says Goliasch. Connection points are every 100m.

As well as the mobile cabins, there are refuge cabins at the front and back of the TBM trains. "We also have automated 'explosive' fire suppressing units," adds Goliasch "called DSPA. This is the Flameguard Dry Sprinkler Powder Aerosol extinguisher from Switzerland."

The sound of the units going off is something to watch out for in a fire he says, "it is not an explosion."

Below: Thrust rams on the Wirth-CREG TBM have impressed the contractor





Central reservation

The finished tunnel has cross passages every 500m for both safety and maintenance purposes, and for tunnel equipment which are excavated by conventional drill and blast methods, breaking through sections of the lining which have been installed with stronger segments then elsewhere. Tunnels are 40m apart.

A wider 50m at the halfway point (of the entire tunnel) will allow for excavation of a third bore in between. This 900m centre tunnel is for an emergency station and refuge. Here there will be cross passage links every 25m for approximately the length of a train. For fire or disaster situations trains will attempt to reach this station or the portal.

The centre space will have seating and emergency supplies for up to two days of survival underground though it is hoped that for most emergencies the second tunnel will be used for rescue before that.

Left: Segment delivery wagons were supplied by Herrenknecht

Below: Despite limited storage, progress is unlikely to outpace production

different types, with many empty spaces.

By keeping a live database of all the individual segments, every one can be quickly located wherever it is positioned within a storage stack.

It and its other ring segments are then be lifted in or out by the four Künz portal cranes running up and down. These have a 50m width and 12m hook height, two with 35t capacity and two 60t.

Segments are located by instructions sent from the database to the crane operators and displayed on an internal screen, setting out coordinates for the crane to go to. Each crane has a radar positioning system accurate to a few centimetres developed by Symeo.

The order comes through from an IRIS segment control system on the TBM. This is another software system initially developed by Strabag subsidiary Züblin which is used to select, order and position ring types as the machine moves forwards. It keeps track of the geology, cross passage location and installation history to choose the necessary ring type required next.

An 'order' goes out to the VMT system to find and deliver the right ring, aged properly in the yard to the necessary strength.

"We integrated the two systems to allow a seamless placing procedure," says Lange "and to organise our limited storage." The storage serves for one month of output from the factories, which can produce 16 rings a day he says. It should be enough for the completion of the project.

Currently the progress on the TBMs has speed up somewhat says Goliasch but its unlikely to outpace production. It is not possible to predict how much the progress will increase, as the rock continues to be variable.

STILL TO COME

New challenges coming on the contract include possible higher temperature in the rock as the highest overburden is reached. This will not be as great as on the 1,800m deep Gotthard Base Tunnel, for example, but could possibly exceed the maximum allowable 30 degrees.

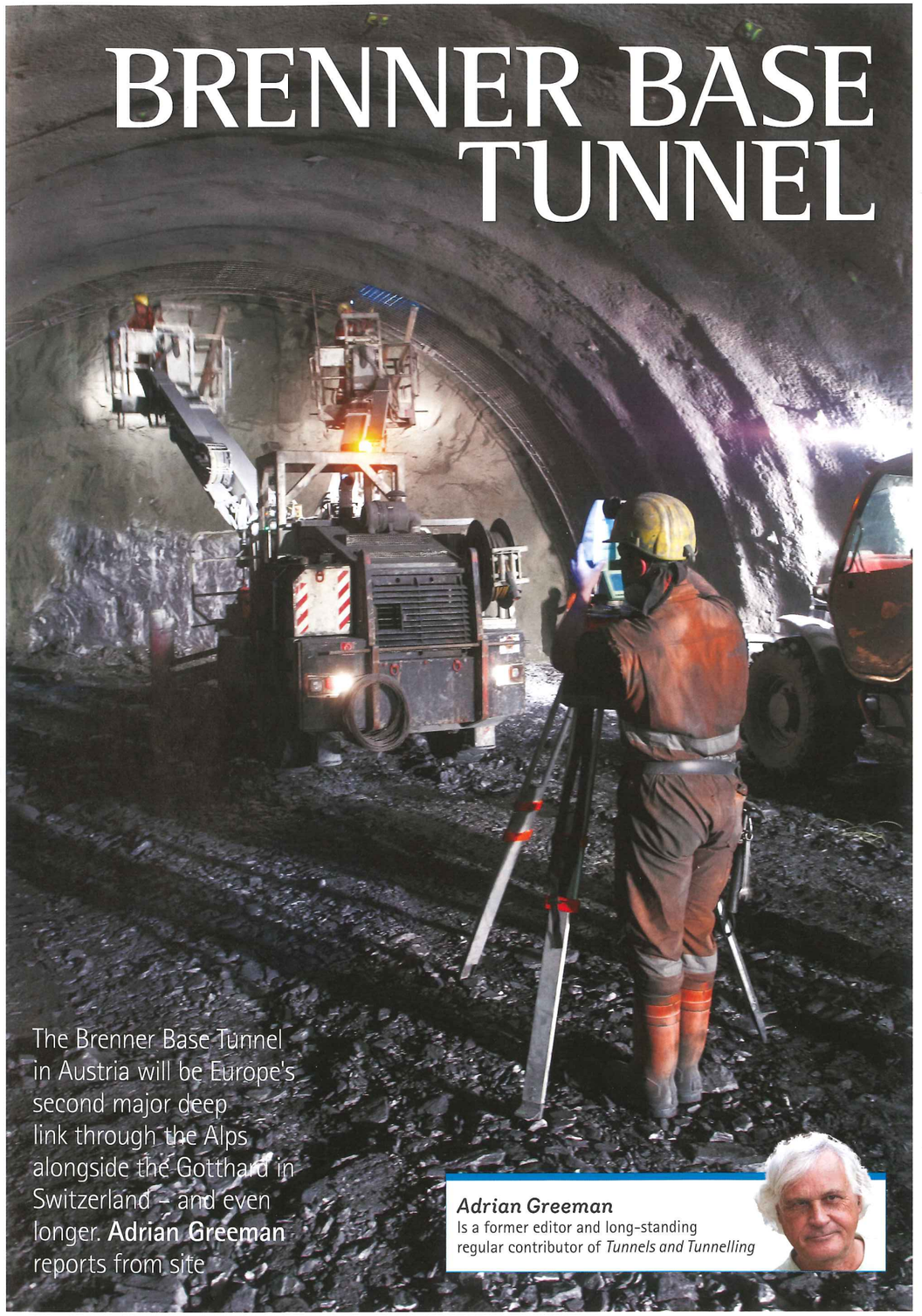
Cooling systems are standing ready to supplement the ventilation.

The construction will also shortly reach the location of the central safety station (see box above).

Meanwhile contractor Porr was last year awarded the contract for the final section of the tunnel Kat 3. The southern bore will be made using conventional methods, widening a 6.3km long exploratory tunnel already made and extending it to 10km.

On the north side preparations are in hand for assembling a TBM to make the longer 12km drive required there

BRENNER BASE TUNNEL



The Brenner Base Tunnel in Austria will be Europe's second major deep link through the Alps alongside the Gotthard in Switzerland – and even longer. **Adrian Greeman** reports from site

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

CONSTRUCTION MOMENTUM of the Brenner Base Tunnel in Austria and Italy is now reaching full speed. Nearly all the preparation, access and exploratory works for the project are either completed or well underway. Last of the major access contracts was let at the end of last year and design documentation is nearing readiness for tendering the main tunnels drives later this year.

Brenner is a huge scheme comparable to the record holding Gotthard tunnel project in Switzerland, due to come into service at the end of next year. That will be the world's longest transport tunnel at 57km in length.

At the end of construction in just under a decade's time, the Brenner will have created a second comparable tunnel link through the Alpine ranges, connecting Italy and the Mediterranean with northern Europe. Services are scheduled to open at the end of 2026.

Depending on how it is calculated it will either be just under the Gotthard's length at 55km of twin bore tunnels, connecting the city of Innsbruck in Austria's Tirol region to the Trentino region in northern Italy, or 64km. The latter figure will include a 9km long section of existing tunnel from Innsbruck eastwards which will allow some through trains to bypass the Innsbruck station and head on for major destinations northwards. Connection links between the twin Brenner bores and the double tracked bypass are currently in construction as part of the latest contract on the Austrian side which also includes access tunnels, caverns, and a new safety tunnel to upgrade the existing bypass.

"Long distance trains taking this route will leave the Innsbruck line at a point just before the city" explains Simon Lochmann, a spokesman for the Brenner Base Tunnel company. BBT-SE has been especially set up as the client for the project as a joint venture between Austrian federal railways and the Italian railways, and is overseeing the project.

Through trains will be heading for major destinations like Vienna and Berlin along what will be one of Europe's major transport corridors.

BASICS

The Brenner is a so-called base tunnel like the Gotthard, the 35km long Lötschberg also in Switzerland and the Koralm in Austria (see feature, page 26). That means it runs exceptionally deep in order to keep the gradients low, at 6.7 in 1,000 on the Austrian side and four in 1,000 on the Italian. Its highest point will be at 795m and overburden will be up to 1,800m, almost as deep as the Gotthard which went over 2,000m.

Above: The Brenner Base Tunnel forms a key part of an enormous north-south link

The advantage is that high speed trains can run virtually at grade allowing up to 250km/hour speeds while while heavy freight can go at between 120-160km/hour with only one locomotive needed. But the disadvantage is that construction is more complex. For the Swiss project that meant coping with squeezing ground in some sections and potentially difficult running sand at one point and the Brenner will face similar difficulties.

The high cover also means high rock temperatures. Long drives mean challenges for ventilation anyway, and providing cooling on top adds to the difficulties of keeping working conditions reasonable. European standards limit working conditions to 28°C but at the deepest point the rock could be 45°C.

"Geology on the northern end of the project **was the more problematical.**"

CHALLENGES

While cooling requires no particularly advanced technology, it does complicate logistics requiring use of industrial air-conditioning units at the right places, and sufficient cold water supply to transfer the heat outside to cooling towers.

Like the Gotthard the Brenner also faces potentially difficult areas of faulting between the great blocs or "massifs" of the Alpine range with rock expected to be highly damaged by tectonic movements. The biggest is the Periadriatic fault in the south of the project where a length of between 500m and up to a kilometre was feared to be exceptionally difficult. As described below, initial works through this zone have turned out better than expected.

The geology of Brenner falls into in the eastern half of the range where the tectonic layering is different to Switzerland. Detailed investigations have been underway since the early days of the project and altogether some 35km of core drillings from the surface have been taken since around 2000.

Along with other data and historic records they demonstrate that substantial sections in the central part of the route are in slatey Bündner schists, a fine-grained layered rock of mainly metamorphosed marine sediments. There are lengths in gneiss and a very hard Bixner granite at the southern end (see cross section). For much of the tunnel's length the excavation will be able to use hard-rock TBMs it is anticipated.

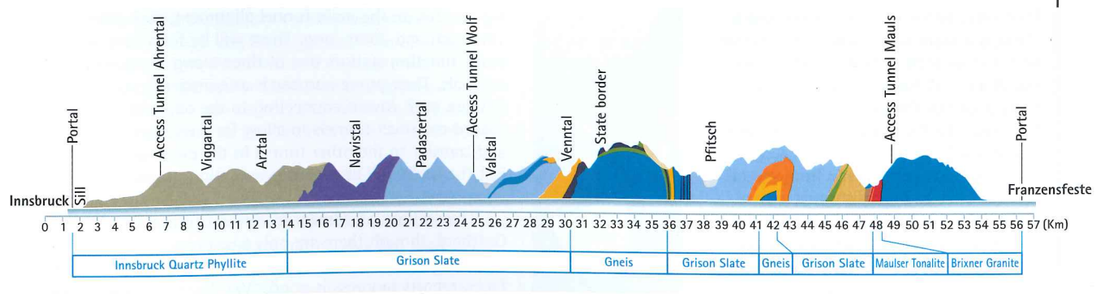
But the northern end of the project was more problematical. The zone around Innsbruck is a softer material, Innsbruck quartzphyllite and it was uncertain if this could be tackled with TBMs at all says BBT excavation geology team leader Heimo Schierl on the Austrian side. In particular there had been severe squeezing ground problems for the Innsbruck bypass tunnel built in the 1990s, with convergences of a metre or more.

Early contracts, excavating a small advance bore have helped assess conditions. Unlike the Gotthard the Brenner has chosen to use a three tunnel construction, with two main running tunnels of 8.1m final diameter set between 70m and 40m apart; these will be linked every 330m by cross passages. But 12m below that runs a service tunnel of just under 5m inner diameter.

"There are great advantages, despite extra expense' says Lochmann. "In operations, the tunnel provides a main drainage path, relieving the main bores. It also gives maintenance access and limits shutdown of the main tunnels, for example when unblocking drains." Safety is better and vehicular access in emergencies. For main tunnel construction there are additional routes for mucking out.

For now the most important function is as an exploratory tunnel ahead of the main construction for a better picture of the geology and rock behaviour. This early contract let in 2011 was therefore a 6km long exploratory drive from the Innsbruck southern suburbs, carried out with drill and blast using a Sandvik jumbo. Work included a large cavern at the end for a TBM assembly and a side access tunnel of 2.14km length from the

Below: Geological section along the Brenner alignment



Network upgrade

Brenner is one of three major Alpine tunnel projects, in Austria, Switzerland and the Freyjus pass from Turin in Italy to Lyon in France.

"But Brenner will be the most heavily used with the largest freight loads" says Lochmann. "It is at a lower altitude than the others, and often more snow free in winter."

It was also the first to get a railway link he says built in the 1860s and still in use. Capacity was doubled 30 years ago with 242 trains passing daily and room for 260. "Noisy trains go past the little villages and towns in the valleys every five minutes or so."

Some 70 per cent of freight load also passes on tens of thousands of trucks along the motorway, over two million trucks annually," says Lochmann.

Brenner is intended to divert some of this providing a much easier flat path through the mountains. Freight trains will double to 4,000t and no longer require twin locomotives for the climb, or three to brake them coming down.

For passengers the tunnel, like Gotthard, will shave significant time from not just Austro-Italian routes but also routes from Germany, Poland, and the Baltic to the whole of Italy.

The old line will now have capacity for regional passenger trains says Lochmann.

The link is a key part of the route corridor from Berlin to Palermo in Sicily, a designated European transport network route, (NET), and top of Brussels' list. Huge amounts of work are being done elsewhere on the corridor, with German railways currently completing over 20 high speed rail tunnels on a new line from Berlin to Nuremberg. Some 40km of high speed approaches north of Innsbruck have been open for a couple of years and have "significantly improved the environment" says Lochmann.

This river valley line connects the city to Munich and then on to Berlin. Meanwhile Italy is completing line all the way to Naples and ultimately via the giant Messina bridge to Sicily.

Brenner will attracts significant European Union funding, says Lochmann, some 30 per cent of the overall capital cost. Austria and Italy provide the rest.

Ahrental, a nearby valley. Contractors Strabag and Porr in joint venture completed this work in autumn 2013.

"There was a small amount of squeezing experienced in the tunnel" says Lochmann "but progress was much better than feared. It suggests that it is possible to go through this rock with a TBM for the main drives."

Schierl explains that while the rock is the same, different conditions were experienced compared to the bypass work. It is orientation of the fairly vertical rock foliation which makes the difference; it lies east to west and "that means it is parallel with the drives on the bypass" says Schierl. "This means weakness between the layers cuts through any arching effect that can be achieved."

Going south however cuts through the rock effectively at right angles and each layering is able to achieve arching effects. "You may have some instability for one round of excavation but it will only be for a metre or so." Potential jamming of a TBM is much reduced if not eliminated.

TBM DRIVE

The possibilities are being further tested in Innsbruck where a TBM drive is set to extend the exploratory tunnel 15km to the south, one of the biggest drives so far on the project. The Herrenknecht machine will be assembled from June onwards in the starter cavern already built and begins its drive later this year.

The importance of the TBM option is not just in getting through the geology but also for tunnel logistics on the longer drives, says Schierl because ventilation and mucking out issues are easier to handle. There is only one access point for the drive and will be also for the main drives.

The TBM work is part of a EUR 380M (USD 417M) multipart contract let to Austrian contractor Strabag with Impregilo (Selini) from Italy in September last year. Work also includes completing more access points in the Innsbruck area and a long 9km drill and blast drive parallel to the bypass tunnel. "That is a small service and safety tunnel with a cross section of just 35m²" says Lochmann. "It has cross connections every 330m to the main tunnel to bring the bypass to the same safety standards as the rest."

The drive is being made from several faces at once to limit disruptive effects on Innsbruck suburbs and because of the need to proceed slowly with heavy ground support. Being east to west there will be squeezing to contend with.

Above: Cifa Spritz System in operation at Brenner

The JV's work does not end there. It is also building the two slip tunnels that connect the future main tunnels to the bypass. These have a relatively complicated twisting geometry, not least because they also connect onto the opposite side tracks at the end. That changes the direction of the trains coming or going to Italy which uses opposite sides for the up and down lines.

"For the trains continuing on to Innsbruck we have permission to use the 'wrong' side at the main station with a crossover point outside the station if they continue north" says Lochmann. A last part of the JV's work is building two big caverns on the main tunnel alignment, each 30m wide 19m high and 200m long. These will be for a so-called multi-function station, one of three along the tunnel at 20km intervals. Their prime purpose is as emergency stations and refuges, each cavern connecting to the opposite side by closely spaced crossover tunnels to allow for passenger evacuation and transfer to the other tunnel in the event of fire or disaster. But the MFSs will also house ventilation, signalling and other equipment.

The stations are similar in concept to those on the Gotthard, though there are only two there.

Currently the contractor who is working at six separate faces, reports progress is good. "We are using Atlas Copco three-boom jumbos for the drives," says technical machine leader Karl Schuster for the JV "doing a 2.2m round in about four and half to five hours." He says there are three eight-hour shifts working round the clock on each tunnel.

There is plenty of room in the access tunnels for regular wheel loaders and Cat 730 dumptrucks for the spoil.

PROGRESS

In Italy meanwhile exploratory works have also been delivering good news. First contracts at the southern end were for a 10.5km length of the exploratory tunnel, driven from the village of Aica through very hard granite. A seven firm consortium including Seli, Pizzarotti and Condotte used a reconditioned Wirth TBM with a Marti conveyor system. A smaller 1.7km side access tunnel was also driven by drill and blast from the Mules valley to join the end point of this drive. Both were finished in 2010.

The two projects prepared the way for potentially the most difficult work on the whole project, the drives across the Periadriatic fault. An EUR 70M (USD 77M) contract for a 1.5km length of both exploratory tunnel and two main running tunnels was let in 2013 to local contractors PAC and Oberossler. It also included two TBM assembly caverns, 33m wide, 19m high and 180m long, ready for the main drives south.

But all eyes have been on the progress across the fault. Investigations here suggested potentially highly disrupted ground caused by tectonic movements between two of the Alpine blocs says BBT investigation geologist Andreas Töchtler. "It is the largest in the Alpine chain with brittle deforming rocks from intrusions of tonelite. Crushing could extend over 500m wide. The biggest fear was that there would be a lot of water, both a problem in itself and also interacting with the rock."

In the event however the drives have gone much better than expected says his colleague Stefan Skuk, the BBT geologist on site. "Actually we had two faults, the smaller Pustertal first of all with crushed granite across about 220m, followed by some relatively firm tonelite and then the main Maulsertal" – Mauls is the Austrian name for Mules.

The second zone has a variety of rocks including phyllites, schists and quartzite and came in repeating layers of fractured rock, then core rock then fractured again along a section of about 800m width.

"The rock is like gravel and you can excavate it with a hydraulic hammer; in just a few places we needed to used drill and blast" says Skuk. To get through this crumbled area the contractor was using mostly an "Italian method" of fairly substantial support including face support anchoring and forepoling above the tunnel face to protect from any falls. In the excavation there were radial anchors up to 6m long and shotcrete with fairly heavy arches.

Excavation went in 1.2m steps. "Support depends on the class of the rock of course" says Skuk "but the face anchors were perhaps 8m to 12m using

Environmental concern

Environmental concerns are important in the project says Lochmann. This has been a guiding principle for selecting access and disposal sites, to ensure the vast amounts of spoil, some 17Mm³ can be placed in locations near to the portals, primarily using conveyors, so that truck movements are eliminated through the mountain towns and villages.

"We will also use as much material as possible for concrete and other tunnel construction material he says. Sites like the Wolf access have major crushing and recycling facilities already; primary crushing is done inside the tunnel to reduce noise.

Water is also important – almost 'holy' comments one geologist wryly - and early work included detailed surveys of springs and sources in the mountains. Over 1,300 monitoring points have been established to track impact on groundwater during the project.

steel and the forepoling was 12m to 16m. Fibre glass face support was also used but steel is preferred because it could be separated from the spoil which was taken away on a conveyor system along the exploratory tunnel.

Though progress for this section has been painstaking, the great discovery was that there was almost no water at all says Skuk. "It may be because of north-south compression on the fault keeping the fractures tight."

The contractor has now completed the required 1.5km length of exploratory tunnel and almost all the twin main bores behind. "We are not quite out of the fault but a forward core drilling of 150m from the exploratory seems to have reached good rock" says Skuk.

The two big caverns have also been done and a couple of smaller caverns to be used for logistic purposes. Cross passages will give truck and conveyor belt access between the main bores once they begin.

In Italy work is advancing at the south end where the tunnel will be completed with a cut and cover section into the Isarco river valley. Some 4.3km of tunnels have to go under the river, an autostrada, a road and a railway. Additional tunnels 2.3km long will connect to the rail system near Bolzano. Strabag and Impregilo were recently awarded the EUR 301M (USD 330M) design and construction work whose river diversions and complexities are is expected to last eight years

BBT has also been preparing access points and spoil disposal areas for the main drives to come. Mules and Aica serve this purpose for the Italian drives south and north, the latter meeting up with drives coming from Austria.

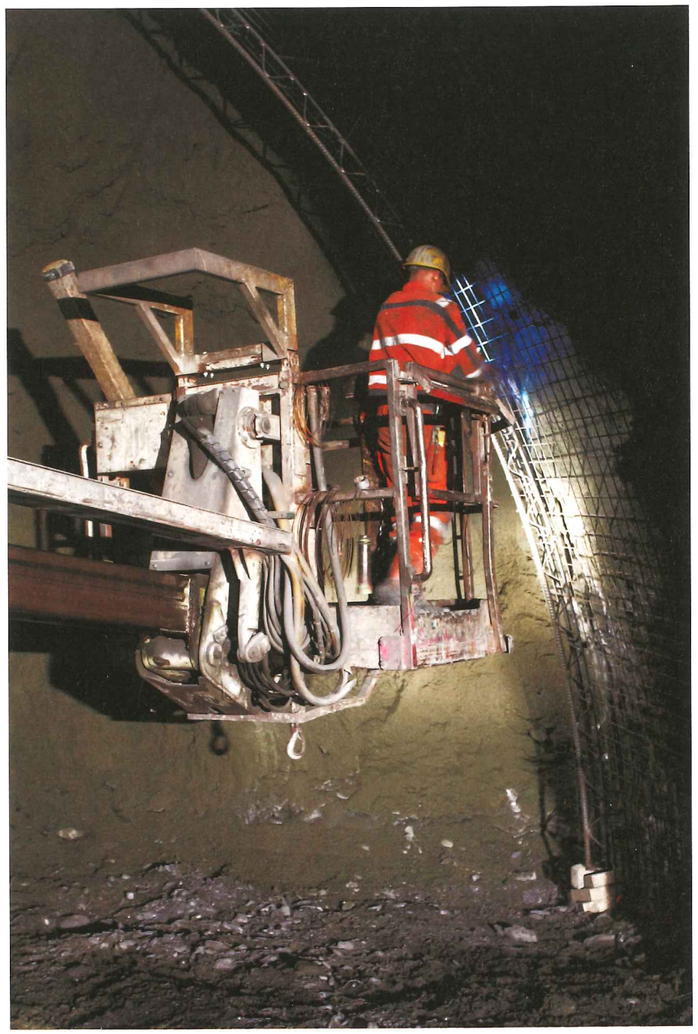
A major site in Austria is the Wolf access. First works here installed a short tunnel underneath the Brenner pass motorway to allow construction access to build a bigger tunnel access adit. A second contract here is now halfway through building a 4km long 1:10 gradient access to the main tunnel line. Later caverns will be built for launching five TBMs in total for north and south main tunnel drives. A MFS goes in at this point too.

"Access work also includes a shorter cross tunnel over to the next door Padaster valley" says Lochmann. The short tunnel, already completed houses conveyor systems underground to reduce noise and dust impact on the environment and nearby villages, carrying spoil initially from the access tunnel and then the main bores. The valley will be filled with spoil and eventually landscaped as part of a local disposal programme for the project (see environment box). "To use the valley we have built another 1.5km tunnel down the valley to divert its river during the project," says Lochmann. "It will go back later into the landscaping but the diversion will then be used as a flood relief path which is needed anyway."

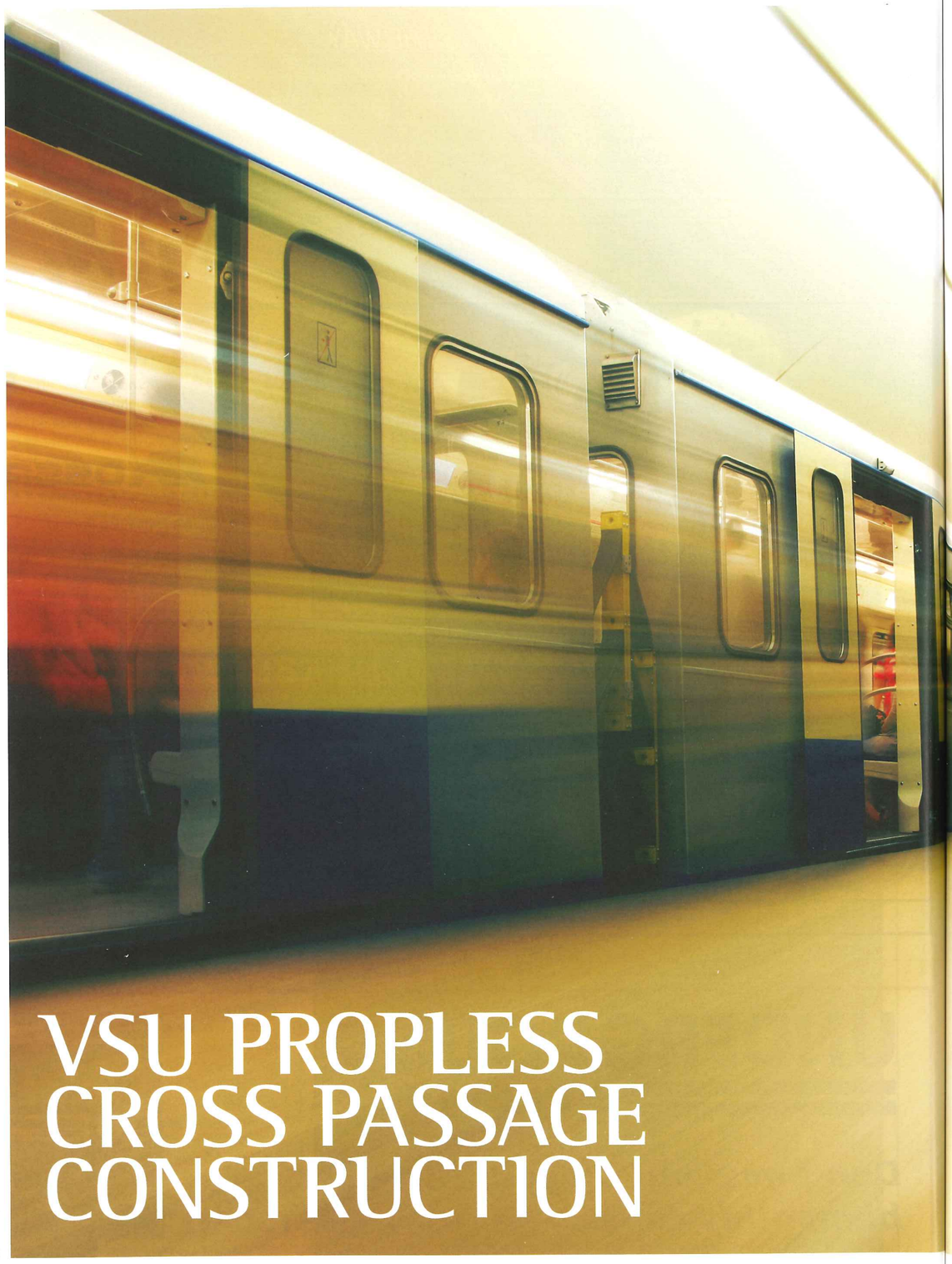
Local contractor Swietelsky is carrying out the work which has another year to go. With most of the access points underway the stage is set for the main works, completing the service tunnel and the twin main bores. Tenders from Mules to the border, around 15km plus, will be ready this spring and also from the Wolf access south. The section from Ahrental, where the MFS is under construction is being worked on and could be ready for tender at the end of the year.

These sections will be big; at least EUR 1.5bn (USD 1.65bn) it is estimated and EUR 1.8bn (USD 1.97bn) from Innsbruck south.

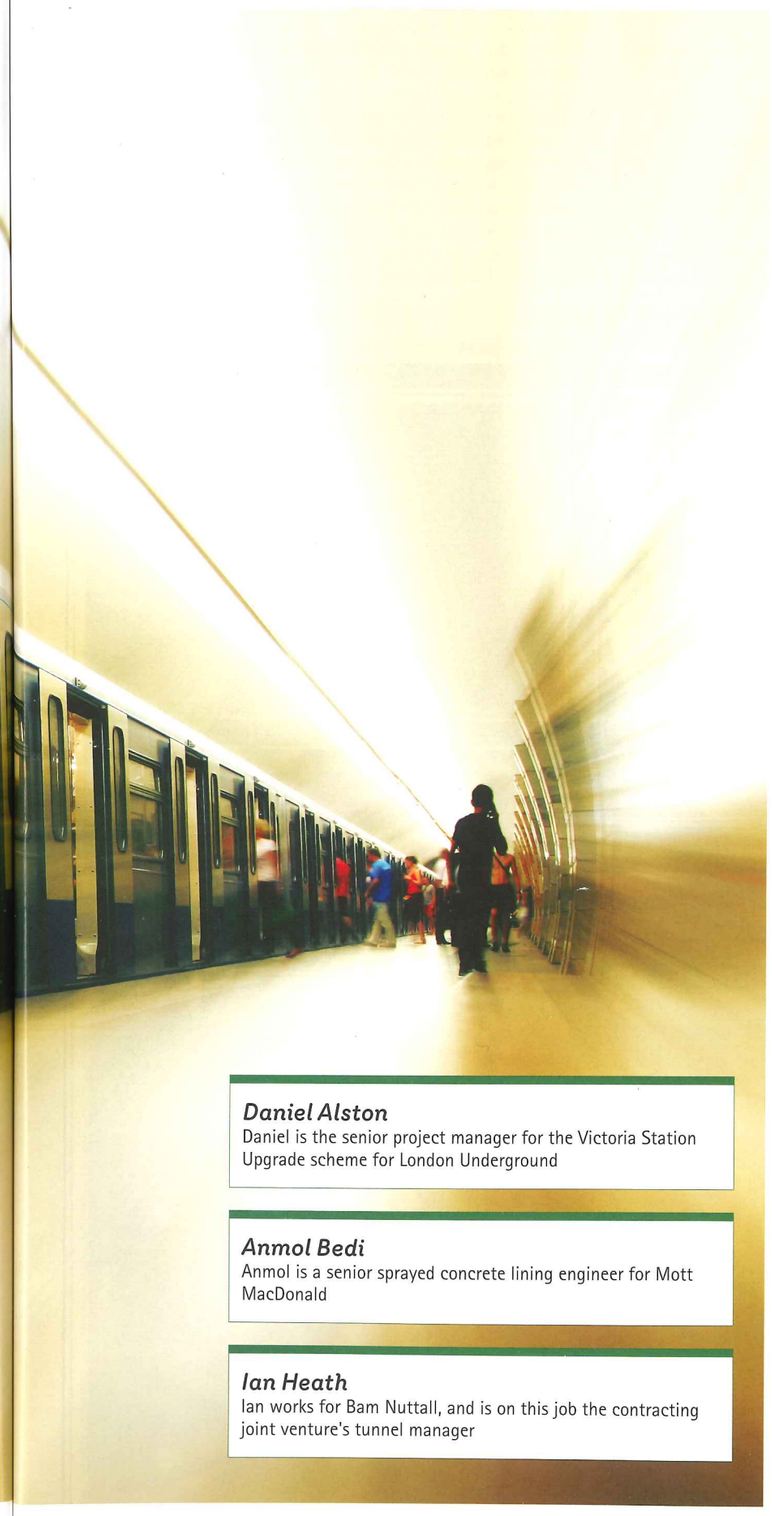
After that there is a whole period of rail track installation, and mechanical and electrical works to come. One thing is for sure, this is not the final report on the project



Below: Progress has been painstaking in places, but water ingress has been less than expected



VSU PROPLESS CROSS PASSAGE CONSTRUCTION



On Thursday 15 January, the British Tunnelling Society was treated to a lively presentation on techniques being used at Victoria Station to allow connections of new tunnels with existing platform and concourse tunnels . The three speakers were **Daniel Alston**, senior project manager for *London Underground (LU)* on the scheme, **Anmol Bedi**, senior SCL engineer for *Mott McDonald* and **Ian Heath** of *Bam Nuttall*, who is the contracting joint venture (TWBN)'s tunnel manager. The talk illustrated the innovative approach taken to forming connections with the operational station at VSU

Daniel Alston
Daniel is the senior project manager for the Victoria Station Upgrade scheme for London Underground

Anmol Bedi
Anmol is a senior sprayed concrete lining engineer for Mott MacDonald

Ian Heath
Ian works for Bam Nuttall, and is on this job the contracting joint venture's tunnel manager

LONDON'S VICTORIA Station is a major transport hub for the city. At a throughput of 82 million passengers a year, it has to deal with more passengers than London's Heathrow Airport. The underground station provides access to the District and Circle line at the high level, running roughly east-west and the Victoria Line, at the low level, running roughly north-south. The LUL are currently in the process of upgrading the station with the objective of relieving passenger congestion and allowing for future growth in use. A new northern ticket hall is being built, the existing southern ticket hall is being expanded, new connecting tunnels built, and escalators and lifts installed. The tunnelling comprises approximately 360m of SCL tunnels and 30m of traditional London Clay square work tunnelling.

One of LU's guiding principles in appointing a contractor was that the work should be carried out using the least number of closures and disruption

to the existing underground platforms and tunnels. The new expanded station would be constructed while keeping the existing station open.

THE CONTRACT

LU appointed the Taylor Woodrow / Bam Nuttall joint venture (TWBN JV) in May 2010 as their design and construct contractor on the scheme. The existing preliminary design was novated to the JV who were then responsible for completing the design with their designer Mott MacDonald (the Designer) from RIBA stage E through to achieving LU compliance.

The inherited design showed propping works to all existing tunnels where new connecting tunnels were to be joined. This approach could require the removal of finishes within existing tunnels, the loosening of ring bolts, and installation of massive steel props and barriers, all to be carried out in extremely limited engineering hours possessions. As part of the design development the JV were keen to amend these designs, with the aim of doing as much as possible behind hoardings, with minimal impact upon the existing operational tunnels. The JV's solution would ease logistics, with all resources being provided from within the site boundary, be simpler to build and would give better programme and risk certainty.

Consequently, the removal of props and intrusive works on the 'live' platform side would mean the station could remain fully operational during the construction works, with an insignificant reduction in platform width. This would ultimately increase passenger safety, especially during peak hours.

The JV had at the earliest stage of its tender identified that the design of the tunnel to tunnel connections was key to the success of the project. During their tender the JV tested a number of different designers to establish the strengths and weakness of that supply chain and establish a simple way forward for the connection works and other temporary works.

Alan Auld Engineering (AAE) were one of these designers who had provided a temporary works solution for an emergency services access tunnel between the Victoria Line platform tunnels relying solely upon square props installed within the new tunnel during construction and no props on the existing platform tunnels.

THE DESIGN

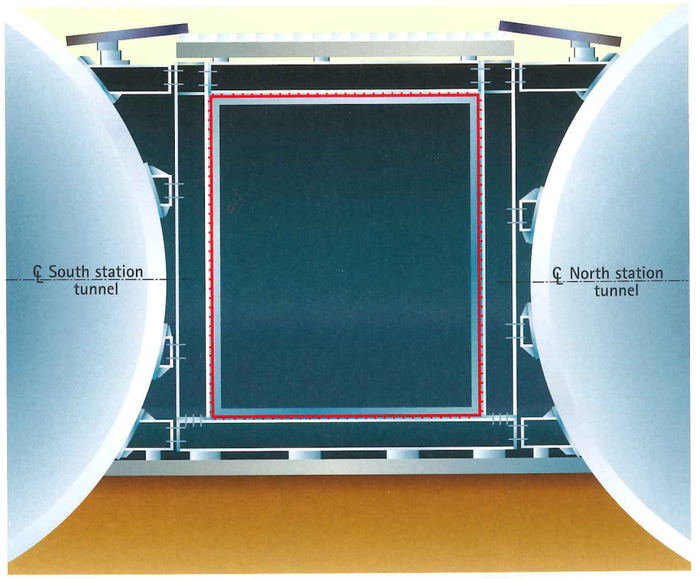
Although the task was relatively simple for the designers and construction team in its brief, it was not as simple in its execution. Many of the existing tunnels at Victoria are at a shallow depth, in water bearing ground and the site is in a confined area within a very busy part of London.

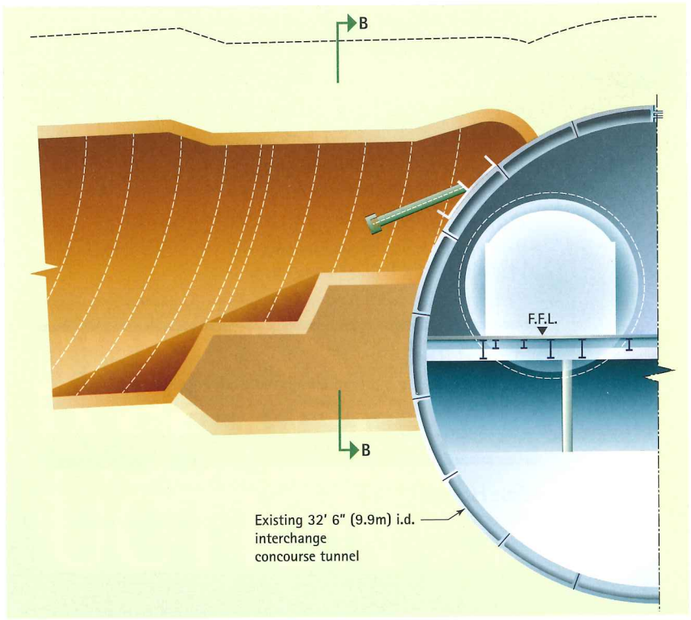
Propping within existing tunnels at connection locations has always been provided previously to counter the distortion of the exiting ring towards the area of excavation caused by the asymmetric unloading of the ring.

In order to prove the feasibility of the new solution the designer developed a novel model that would provide a more detailed assessment of joint segment behaviour than that based upon the Muir Wood1 Empirical Model.

Below, top: Frames between platform tunnels at 0.5m centres from the non-operational side

Bottom: Side elevation of SCL tunnel being advanced towards existing tunnel





Questions from the floor

John Elliot of Alan Auld Engineering, designer of the tunnel temporary works at VSU congratulated the team on an excellent presentation and asked what the team would do differently next time. He stressed in his own view that design development of permanent works, temporary works and methods should be run together to provide a robust solution.

Ian Heath answered that more work should be put into defining the various parties' scopes to prevent the overlap between temporary and permanent works design packages of that was experienced at Victoria.

John Elliot asked what deformations were experienced in the existing platform tunnels due to the construction of PAL 16 – the emergency services tunnel.

Anmol Bedi answered the measured deformations were in the order of 10mm – this was lower than the initial predictions undertaken by the designers as part of the potential damage assessment.

Alex Lowson of Mott McDonald and structural steel designer for the scheme asked what degree of stiffness did the jet grouted ground confer on the existing tunnel in practice.

Anmol Bedi answered that the team were unsure as no strain gauges or load cells were placed on the structural steel props, but what was clear was the braces and cross strut could have been done away with as the jet grout was much stiffer than expected.

Steve Parker of Ferrovial asked what temporary works was necessary to install the various steelwork temporary works.

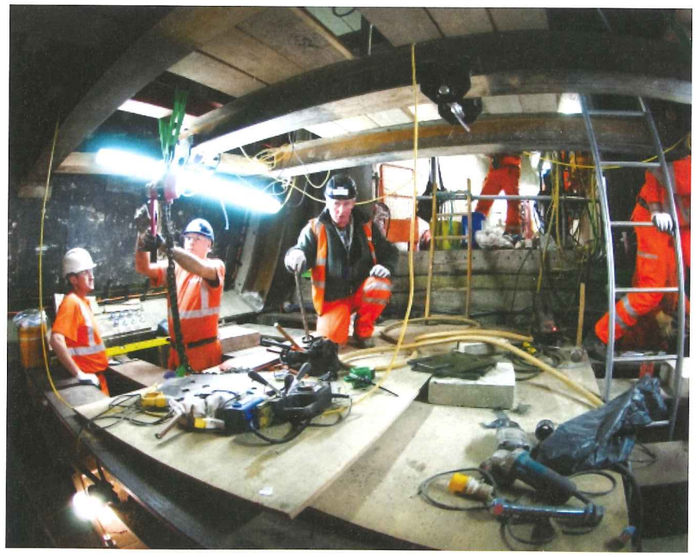
Ian Heath answered that in most cases lifting was facilitated by air winches placed on purpose built tables bolted to the shotcrete and with hawsers running through snatch blocks again bolted to the shotcrete. In the case of Pal 16 the emergency services tunnel Specialist Plant designed a bespoke bogie mounted lifting system.

Colin Mackenzie, retired, commented that he had been section engineer on the Victoria Line at the station 50 years ago and again 20 years ago as director on the congestion relief scheme. He asked whether the hoop stress taken by the segments to be removed was designed to be taken out by through bolts in shear.

Anmol Bedi answered that this was correct and that additionally the top lintel of the frame was to be concreted in.

Colin Mackenzie further commented that in his experience bolt loosening at openings was not the correct way to secure an opening using the traditional method, and his practice was to tighten the bolts around an opening to stiffen the tunnel.

Ian Heath answered that this has not been the generally accepted view at the recent King's Cross Redevelopment works, which had led to the JV attempting to find a different approach.



The shallow tunnels and proximity of existing LUL assets required a more rigorous approach, and as the basis of the model the designer developed a closed form solution to assess joint stresses, based upon the D.J. Curtis Equations, to include rotational joint stiffness.

In order to provide ground stability, the water bearing ground around the existing tunnels had been jet grouted.

The proposed method for the connection was to advance a top heading in SCL to the top of the new opening and then use the combination of a bolted frame attached to the outer existing lining forming the opening and propping off the new SCL works.

The model had to recognise the extra stiffness conferred by the jet grouting in the upper half of the existing tunnel and be able to ascribe the effect of various degrees of existing lining joint opening so a contingency method could be put in place based upon a gradation of trigger levels.

The model also had to recognise any degree of ovality already built into the existing lining.

The model then had to identify which element of the existing ring was most likely to fail and the degree of ovalisation/joint rotation that this failure would occur at. In order to predict the existing level of stress in the lining, the JV carried out a detailed ring ovality survey in each location of a proposed opening.

The model was then developed to stipulate the deflection or joint rotation at which the ring component elements would distress and what level of stress would be likely caused by the JV's proposed excavation works.

The outcome of the model was a series of deflection and joint rotations of the existing ring that the joint venture could readily monitor as excavation proceeded using standard instrumentation and monitoring equipment installed on the cast iron segments of the tunnels.

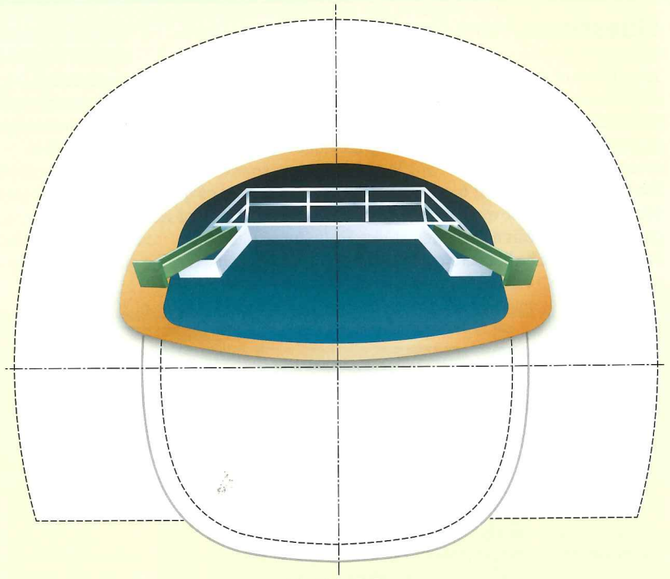
CONSTRUCTION OF JUNCTIONS

The presentation provided a number of case studies of the method of junction construction only two of which are mentioned here for brevity.

The opening at paid area link

The PAL 7 opening was a relatively simple example of the opening method in use and involved the connection of an SCL tunnel in to an extremely busy concourse tunnel providing a passenger connection between the District and Circle Line and underlying Victoria Line. The impact of the traditional style of propping into the concourse tunnel would have hindered the capacity of the tunnel to deal with peak passenger flows. The JV's method of forming the opening was to approach the back of the lining in an SCL top heading, form the top half of the opening steelwork behind the lining and prop forward off additional sprayed concrete footings.

The bench and invert were similarly constructed to allow for the



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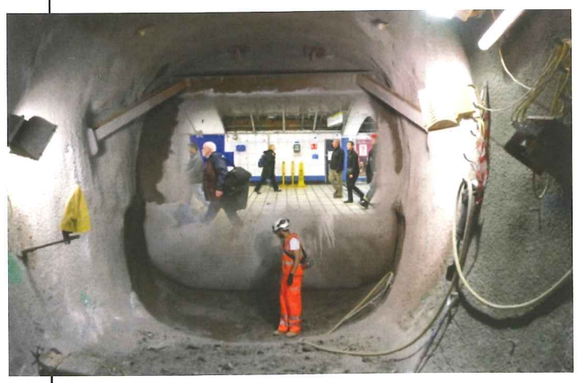

completion of the remainder of the jamb frame. All steelwork was installed using air winches and snatch blocks with appropriate holding down bolts which were secured onto the shotcrete.

Emergency access tunnel

PAL 16 involved the construction of a 28m-long emergency services access tunnel between the two platform tunnels of the Victoria Lining. Traditional methods would have involved propping over a significant length of each platform tunnel and the unwelcome restriction of passenger use on two very busy platforms. The JV's solution required no propping within the existing platform tunnels. The construction of the tunnel comprised the excavation of 500m³ of tunnel muck and the installation of 72t of structural steel. The excavation was advanced in a series of timber headings with crown bars to support the timbering prior to installation of the steelwork frames which braced the existing tunnels. The JV underlined the importance of the marriage of the permanent works designer, temporary works designer, construction team and specialist suppliers in providing the final solution.

Above: A photo-montage of the works behind the existing tunnel with a superimposed photograph of the existing tunnel in use concurrently

Top right: Front elevation of propping of opening in top heading and bracing shedding load back onto SCL footings

VALIDATION OF DESIGN

The presenters reported that the outcome of the works in terms of induced tunnel deformation was consistent with the model produced and movements in the existing tunnels using the external propping system were within the predictions and set trigger levels. As such, the construction progressed consistently and smoothly through-out the entirety of construction, without the need for any contingency or mitigation measures.

CONCLUSION

The team's approach to making connection works has been successful in preventing significant disruption to the passengers of London Underground using the station. Much had been gained by close liaison with London Underground's station manager and his team and this has helped ensure that the tunnel connection works were completed with no railway possessions and minimal impact to the operation of the station

Rapporteur: Ivor Thomas

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MAKE WAY FOR TBMS

Lok Home, president of TBM manufacturer *Robbins*, argues that TBM technology should be considered for some traditionally drill and blast conditions

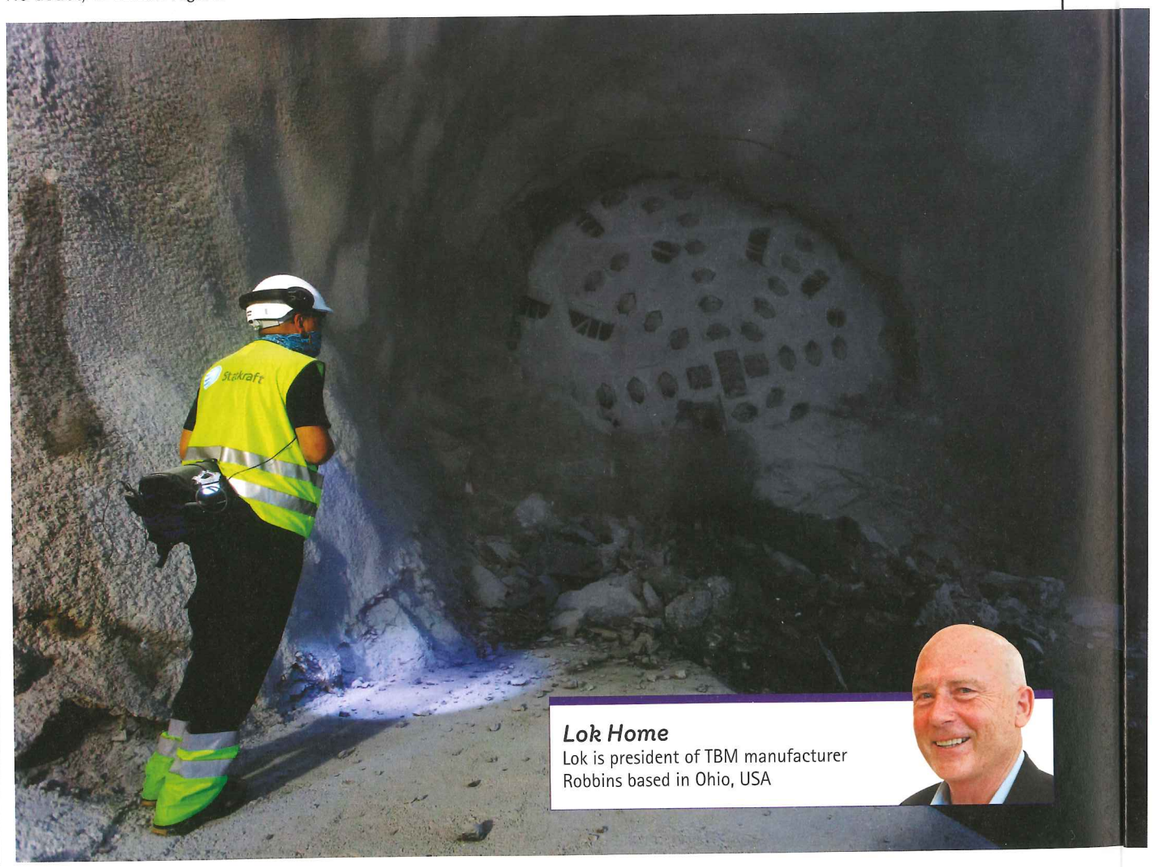
IN RECENT articles, it has been argued that TBMs have their place, but not in difficult ground conditions. Many consultants, owners and contractors adhere to the premise that when conditions get tough, the oldest method should prevail. They often look to decades-old data and previous experience when considering excavation methods, and specify or opt for drill and blast excavation.

Drill and blast (D&B) has been around at least since the early 1800s when tunnels were constructed worldwide using black powder for railroad and mining. Conventional excavation has since become a very refined art with controlled micro-blasting, refined blasting agents, shotcreting, full-face stepped advance, and specialised machinery. It is a very capable method of tunnel excavation in difficult ground. No doubt, in certain regions of the world such as Austria and Italy it has become an art form.

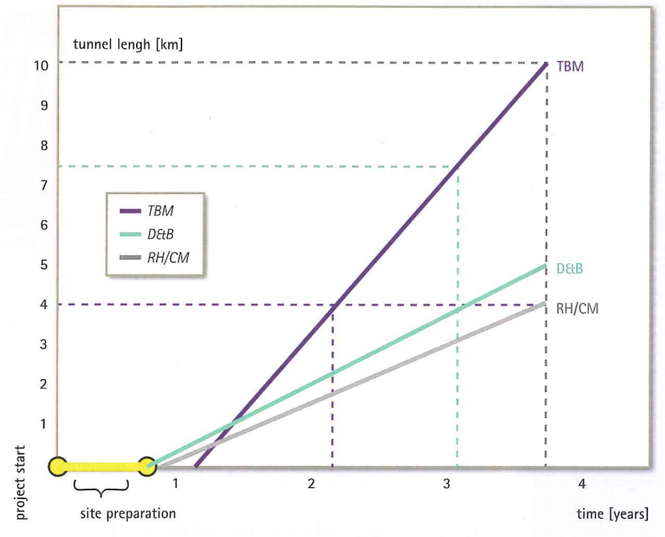
However, those factors in themselves don't mean that other methods such as mechanised tunnelling should be discounted in difficult ground. The facts from tunnelling projects around the world point to lower overall costs when TBMs are used, faster excavation rates, less required ground support, and greater safety.

With today's TBM technology, historic strongholds are crumbling. Drill and blast may be proven, but it has also been shown to be slow and costly in tunnels over 2 to 3km in length. What is better to maximise daily advance – and ultimately safer in difficult ground – is to have the safe haven, potential plug and drill platform that a TBM can provide. A TBM when properly designed can block raveling ground, high pressures, and running ground, making the operation safer if/when an unexpected event occurs. A TBM can quickly provide the means and measures to bring these conditions under control. This is particularly true of Crossover TBMs, which can switch between modes such as EPB/Rock, EPB/Slurry, and Slurry/Rock.

Below: Breakthrough at Kargi in July 2014. The machine, after in-tunnel modifications, achieved rates of up to 723m per month



Lok Home
Lok is president of TBM manufacturer Robbins based in Ohio, USA



Above: Figure 1, A generalised graph showing that despite longer lead times, the higher advance rates of TBMs make them economical for tunnels over 1.5 to 2 km. The two methods are also compared with roadheader/continuous mining methods

The debate as to the method of tunnel excavation requires many factors to be weighed, including tunnel profile, tunnel diameter, project schedule, and more. However geology does not have to be the deciding factor. At current projects such as New York, USA's Rondout-West Branch Bypass Tunnel, contractors are looking at both TBM and D&B methods seriously (Smith, 2015). Construction in shale, gneiss, and granite is expected to encounter significant groundwater as it travels below the Hudson River. A TBM could excavate this tunnel just as safely and efficiently, if not more so, than D&B. In significant pressurised conditions, Crossover type TBMs such as the XRS (Rock/Slurry hybrid) are capable of boring in rock under significant water pressure while lining the tunnel with segments. If water is expected in an unpressurised environment, a Main Beam TBM could be used in conjunction with pre-grouting to stem water inflows. The possibilities are vast when using TBMs.

RELIANCE ON OLD DATA: REDUCING RISK ISN'T ABOUT LOOKING OVER YOUR SHOULDER

Contractors, owners, and all parties involved in tunnelling projects are understandably looking for ways to reduce risk. Components of tunnelling in the underground always carry some risk, as it is impossible to know what lies ahead (and below, and to the sides) of a tunnel with 100 per cent certainty. However, risk reduction shouldn't make us as an industry default to potentially less efficient methods backed by old data.

In recent papers (Singh and Zoldy, 2014), comparisons of TBM versus D&B advance rates, downtimes, and more were used to create a framework as to when to choose each method that leaned towards D&B. Such papers are well-researched and are very informative, but do they take into consideration all the current technical advances?

Much of the framework is based on data from papers more than 15 years old. Like many technologies, TBMs have advanced significantly in that time frame.

Some of this may be a result of our industry's reluctance to share data—we as manufacturers, contractors, and consultants should be more open when contracts allow for it so we can all benefit from recent field results. Indeed, I am looking forward to an upcoming paper at this year's RETC show in New Orleans by Kenny Construction's Brian Fulcher that will provide a more comprehensive and current framework as to when TBMs and D&B are best used (Fulcher et al, 2015).

Many times, even if a tunnel is specified for TBM, a contractor will attempt to hedge their risks with a drill & blast starter tunnel. Today's TBMs, however, are well equipped for difficult ground. In fact, if difficult conditions and fault zones are expected, then countermeasures are built into the design. TBMs are capable and recommended to be launched into difficult ground at the beginning of the tunnel without the use of a long D&B starter tunnel. The use of these long D&B starter tunnels often creates more problems than advantages and encumbers the installation of final lining as the tunnel profile can be uneven. We have seen it in many tunnels. Instead, the starter tunnel should be looked at as an opportunity: What better place to test the machine's and crew's capabilities in difficult ground than near the portal? These skills are usually needed further along in the tunnel excavation in any event. Combining the methods is often more trouble than it is worth.

GROUND SUPPORT: WHAT'S YOURS IS OURS

Any type of ground support used in D&B, from shotcrete to spiles to fiberglass rock bolts, can be used while the TBM is boring. A TBM combines multiple operations including ground support that in drill & blast would be sequential. In a drill and blast heading, first there is advancing (drilling & blasting), then ground support, then muck excavation, all requiring different crews and different specialised machinery. With modern TBMs, ground support can be used to allow lining to be extruded from the machine as it advances - a very safe option. Today's modern TBMs are also equipped with all of the same tools and techniques that are used in D&B operations to excavate through difficult rock conditions. With sophisticated probing techniques installed on the TBM, the operator can predict what is ahead of the tunneling operation more quickly than drill & blast and react

appropriately.

A good example of this is Peru's Olmos Trans-Andean Tunnel. The tunnel is the second deepest civil works tunnel in the world after AlpTransit—below 2,000m of Andean rock. The project, which provides a freshwater conduit to drought-ridden areas on the Pacific Ocean Watershed, languished for decades following multiple failed drill & blast attempts from both sides of the mountain range. The volcanic rock types, from quartz porphyry to andesite and dacite, were so complex and squeezing ground so severe that this type of tunneling was foregone.

In 2006, it was decided to attempt the project again using a tunnel boring machine. A Robbins 5.3m diameter Main Beam TBM was used to excavate the remaining 12.8km of tunnelling. About 4 km into the excavation the TBM began to experience significant squeezing ground and severe rock bursting conditions. In order to keep tunneling, a plan was devised that involved in-tunnel machine modifications. The machine's roof shield fingers, which were being damaged by falling rock and rock bursting, were removed and replaced with the McNally Support System using steel slats. As mentioned above, the system allows the slats to be extruded from a series of pockets in the roof shield (and side support if needed), forming a continuous lining. The system worked and the machine was able to make a successful breakthrough in December 2011, following about 10,000 recorded rock bursting events. This is just one example of how a TBM can be adapted, even while in the tunnel, to excavate incredibly challenging conditions.

TECHNOLOGY: ALWAYS CHANGING, EVER IMPROVING

Both methods, TBMs and D&B, should not be considered statically when making a decision. The latest innovations should always be analysed. Case in point: a recent project in very difficult ground at Turkey's Kargi Hydroelectric project has revolutionised our machine designs for mixed conditions. The 7.8km tunnel in mountainous central Turkey encountered much more difficult ground than was predicted through geological testing. The machine and tenacious Turkish crew were ultimately successful, but went through difficult sections with a 10m Double Shield TBM that would have been best excavated using a Crossover machine with incorporated EPB features. The actual geology was vastly different than predicted and turned out to be very poor and weathered rock; it could not really be called solid rock. Ultimately, after in-tunnel modifications including additional two-speed gearboxes and increased torque, the machine at Kargi was able to excavate the ground very efficiently. The machine even bored 723m in one month—more than twice the rate of a drill and blast heading proceeding from the opposite end of the tunnel. The TBM broke through in July 2014.

The design changes made at Kargi have now made their way into Robbins' Crossover line of TBMs. For instance, the successful canopy drill design from Kargi was pre-installed on a Crossover XRE (Rock/EPB) TBM that will be used on Mexico's Túnel Emisor Poniente (TEP) II Project later this year. The design provides another ring for grout drilling or forepoling close to the cutterhead. As used at Kargi, the canopy drill will operate in the top 120 degrees of the tunnel, while a second probe/grout drill is located further back on the machine, allowing two different patterns of holes. The setup should allow the machine to efficiently excavate in a tunnel expected to be 90 per cent rock with the last 10 per cent in soil. Again, this is just one example illustrating recent improvements made to tunnel boring machines for difficult ground.

THE NUMBERS SPEAK FOR THEMSELVES

It has been proven time and again, and referenced in the upcoming RETC paper from Fulcher et al., that TBMs advance at rates that are typically two to three times faster than that of a D&B operation. Those types of rates more than make up for any increased capital costs or longer lead times that might be associated with purchasing a TBM. At Kargi, average excavation rates after modifications were 407.7m per month, compared to the D&B heading, which in good ground conditions averaged 173.8m per month. Ultimately the conventional heading was stopped as the TBM advance picked up, because of the mechanised tunnelling method's increased efficiency. Those types of rates aren't limited to civil works tunnels either. Montana, USA's Stillwater Mine recently published a paper comparing their TBM headings to their drill and blast headings in very similar geology (Luxner, 2014). The mine has spent the last three decades using a mix of TBMs and drill & blast for mine access and rail haulage tunnels. They concluded that Robbins TBM operations on the 7.1km long Blitz drive were on average 5.75 times faster than their drill and blast heading directly overhead on the next mine level. Despite requiring a larger capital investment, the direct operating costs of the TBM were 14 per cent lower per meter than D&B, more than making up for the capital cost.

The numbers make a compelling argument, and when other factors like safety are considered, tunnel boring becomes a standout method. While we all know that drill and blast can be used in difficult ground, the next step forward is with mechanisation

editor@tunnelsonline.info

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

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What's on

2015

Istanbul Metro Forum and Exhibit
19-20 April 2015
Istanbul, Turkey
The Turkish Tunnelling Society's Subway Working Group is organising this event along with other professional and government groups. Among the objectives of this Forum is to gather relevant administrations, contractors, suppliers and other stakeholders concerned with subway investments in Istanbul, which will achieve a metro system longer and more modern than many other developed cities in the world by 2019.
www.istanbulmetroforum.org

Intertunnel Russia
27-29 April 2015
Moscow, Russia
Intertunnel 2015 will be the seventh in a highly successful series of events enabling engineers and buyers to learn more about the very latest in tunnelling and underground construction technology and expertise. Utilities projects are vitally needed to support Russia's economic development and the industry is growing.
www.intertunnelrussia.com

ISRM Congress 2015
10-13 May 2015
Montreal, Quebec
Held in conjunction with the CIM Convention for 2015, the International Symposium on Rock Mechanics holds its international conference every four years. There will be a one-day symposium on "Shale and Rock Mechanics as Applied to Slopes, Tunnels, Mines and Hydrocarbon Extraction" (ARMA & CARMA Initiative), Chaired by Herbert Einstein of MIT.
www.ISRM2015.com

World Tunnel Congress 2015
22-28 May 2015
Dubrovnik, Croatia
WTC 2015 heads to Croatia as the annual event returns to Europe. The motto of the conference is 'Promoting Tunnelling in the South East Europe Region'. The organisers have said that they hope for a sharing of international experience with local groups.
www.wtc15.com

RETC
7-10 June 2015
New Orleans, USA
The biennel conferece will be held at the Sheraton Hotel in New Orleans, Louisiana this year. The organisers have announced that the 2015 show should be as successful as the 2013 event which had the largest number of attendees, exhibitors and papers in the show's history.
www.retc.org

49th US Rock Mechanics / Geomechanics Symposium
28 June-1 July 2015
San Francisco, California
The 2015 program will focus on new and exciting advances in rock mechanics and geomechanics and encompasses all aspects of rock mechanics, rock engineering, and geomechanics.
www.armasymposium.org/

Bauma Conexpo Africa 2015
15-18 September 2015
Johannesburg, South Africa
The premiere of bauma Africa in September 2013 attracted 754 exhibitors from 38 countries and 14,700 visitors from over 100 countries. Covering a total of 60,000sq.m of exhibition space, this is the biggest event for the sector in Africa.
www.bcafrica.com

Roads. Bridges. Tunnels International Exhibition
23-25 September 2015
St. Petersburg, Russia
Roads. Bridges. Tunnels (the International Specialised Exhibition) takes place in St. Petersburg, Russia from 23 September to 25 September. The trade show is organised by Restec.
www.tofairs.com

ICUEE 2015
29 September-1 October 2015
Louisville, Kentucky
The largest demonstration show in North America for the construction and utilities industries. This biennial show attracts persons involved in the electric, cable, sewer/water, gas, construction and public works sectors. Hands-on, practical desmonstrations of construction and utility equipment are also planned to be held alongside the event.
www.icuee.com

Workshop on Innovations and Challenges in Tunnelling
5-6 October 2015
Kingston, Ontario
Save the date for the TAC 2015 Workshop, AGM and annual awards dinner, to be held at Queen's University's Grant Hall in Kingston. Further details of the workshop including program and registration will be available in Summer 2015..
www.tunnelcanada.ca

Eurock 2015 & 64th Geomechanics Colloquium
7-10 October 2015
Salzburg, Austria
The ISRM Regional Symposium EUROCK 2015 Future Development of Rock Mechanics, is to be held in conjunction with the 64th Geomechanics Colloquium
www.eurock2015.com

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. Since the first meeting in Paris in 1908, it has toured the member countries of the non-government organization, Permanent International Association of Road Congresses (PIARC).
www.aipcrseoul2015.org

ITA Tunnel Awards
19 November 2015
Hagerbach, Switzerland
The International Tunnelling Association has launched its own independent awards to recognise industry achievements. The first presentation will be held alongside a conference and banquet at the Hagerbach Test Gallery.
www.awards.ita_aites.org

Stuva Conference
1-3 December 2015
Dortmund, Germany
Held every two years, this conference sees 1,500 participants and visitors from about 20 countries. It is numbered among the world's leading get-togethers for underground construction experts. In 2015 the chosen venue for this premier event is Dortmund.
www.stuva-conference.com

Building simulation
7-9 December 2015
Hyderabad, India
This conference is the 14th International Conference of the International Building Performance Simulation Association (IBPSA).
www.bs2015.in

2016

International Symposium on Tunnel Safety and Security
16-18 March 2016
Montreal, Canada
Tunnel safety and security is a challenge for both private and public sectors. ISTSS provides a forum to discuss current practice and emerging trends and research in the field of tunnel safety and security. Each day will be opened by invited Keynote Speakers.
www.istss.se/en

NASTT's No Dig Show
20-24 March 2016
Dallas, USA
The overall No-Dig Show program is focused on one objective: helping you maximize your investment in trenchless technologies, services and applications. Owners, utilities and municipalities can immediately benefit.
www.nodigshow.com

Bauma 2016
11-17 April 2016
Munich, Germany
The 31st meeting of the world's largest trade fair for construction machinery, building material machines, mining machines, construction vehicles and construction equipment.
www.bauma.de/en

World Tunnel Congress and North American Tunnelling conference 2016
June 2016
San Francisco, California
The 2016 World Tunnel Congress (WTC) and the 39th General Assembly of the International Tunnelling and Underground Space Association (ITA) will be held in conjunction with the UCA's North American Tunneling conference. Bringing the three events together in the US is unprecendented.
www.smenet.org
www.wtc2016.us

GeoChina International Conference
25-27 July 2016
Shandong, China
This conference will provide a showcase for recent developments and advancements in design, construction, and safety Inspections of transportation Infrastructures and offer a forum to discuss and debate future directions for the 21st century. Conference topics will cover a broad array of issues
www.geochina2016.geoconf.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. Regular BTS monthly meetings are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month.

Harding Prize
16 April 2015
The annual Harding Prize competition is named in honour of Sir Harold Harding, the founder Chairman of the BTS and is open to young engineers aged 33 or under at the end of 2013. Entrants must submit an original paper relating to any aspect of tunnelling they consider of interest to the industry. The winner will be chosen by the BTS Committee.
Speakers: Harding Prize finalists

BTS Annual Dinner
8 May 2015
The BTS Annual Dinner will be held at the now traditional Brewery venue at 52 Chiswell Street in Central London. The event starts at 7.00pm and runs until1.00am. Booking is now open but places are going fast.

BTS Annual General Meeting and East Side Access project presentation
21 May 2015
The East Side Access Project in New York is the first expansion of commuter rail in New York in over 100 years. When complete it will provide a direct link for Long Island Rail Road commuters to a new terminal beneath the existing 100 year old Grand Central Terminal on the east side of Manhattan.
Speaker: Andy Tompson

Tunnelling in the Lambeth Group: how can we stop it going wrong?
18 June 2015
A presentation by a leading geologist with expertise in the interpretation of complex soils and rocks as well as the geology of London and Southeast England.
Speaker: Jackie Skipper

BTS Design and Construction Course
29 June - 3 July 2015
The five-day annual BTS Tunnel Design and Construction Course aims to provide a comprehensive introduction to all aspects of tunnelling. The course speakers are all recognised industry experts in their own fields and drawn from the BTS. Five BTS-sponsored spaces are available.

Innovation and technology in segmental lining design
17 September 2015
A presentation by a tunnel engineer who has extensively published on topics related to segmental lining solutions.
Speaker: Anthony Harding

Waterview Connection project in Auckland, New Zealand
15 October 2015
The Waterview Connection project is New Zealand's largest and most complex roading project. It is due to be completed by 2017, and includes one of the country's most challenging tunnels to-date: 2.4km of 14.1m-diameter twin bores.
Speaker: Chris Ashton

If you have a topic or project you feel would be suitable for a BTS evening presentation, please contact:
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Tunnels & Tunnelling International is printed at Stephens & George Print Group, Merthyr Tydfil.

Tunnels & Tunnelling International ISSN (USPS 7330) 1369-3999 is published monthly by World Market Intelligence, Progressive House, Foots Cray, Sidcup, Kent, DA14 5HZ.
The US annual subscription price is $283.49. Airfreight and mailing in the USA by agent named Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Periodicals paid at Jamaica NY 11431.
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