

AUGUST 2012

tunnels & tunnelling INTERNATIONAL



Central and Eastern Europe
Project reports on the transport schemes driving tunnelling in the heart of Europe

Sprayed concrete
Options, new developments and criticism

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Prague Metro Line A

A return to TBMs for the Czech capital



HAMBURG: 11 BREAKTHROUGHS FOR THE WORLD OF SCIENCE.

In the Hamburg metropolitan region, the 3.4 kilometer long international research facility "European XFEL" is being built. From 2016 onwards, research is to be carried out in this facility into the behavior of molecules and atoms using x-ray laser flashes with tiny wavelengths. The heart of the installation is a 5,777 meter long tunnel system which was excavated by two Herrenknecht Mixshields.

The Mixshields TULA (Ø 6,160mm) and AMELI (Ø 5,450mm) drilled from the target shaft of the future experiment hall and/or the intermediate shafts on the European XFEL research area in Schenefeld beneath residential buildings, streets and fields to the DESY area in Hamburg. The ground with its partly sandy and partly clayey condition posed some challenges, for which the TBMs had to be specially adapted. AMELI produced the fan-like tunnel system at the end of the facility in 8 sections: the machine had to be moved three times through a shaft already completed, and four times it even had to be transported to the surface and then to a new starting point. In the meantime, tunnels at depths of 6 to 38 meters had been completed – preparing the way for obtaining new results in structural research, thus making it possible to develop new materials and more efficient medication.

HAMBURG | GERMANY

PROJECT DATA	CONTRACTOR
S-544, S-545 2x Mixshields Diameter: 6,160mm, 5,450mm Installed power: 450kW, 330kW Tunnel lengths: 487m, 602m, 1,996m, 544m, 220m, 300m, 361m, 141m, 200m, 267m, 660m Geology: till, sand, gravel	Bilfinger Berger AG, Hochtief AG



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comment

London crawling

As *T&T* goes to press in its London offices, and the world watches the city prepare for the Olympics, locals are bemused at the prospect of inviting 5.3 million guests from all over the world to fight for a seat on the aging, and massively over-capacity infrastructure in the UK capital.

Even last year, Transport for London Commissioner Peter Hendy advised the London Assembly officials that commuters should 'have a pint' before journeying home in the evening, just to avoid the busy periods. So that was the plan: have a drink and wait. That is fine, assuming no knock on delays.

The mooted London bus strikes seem to have been called off, which must be a relief for London Underground (LU) bosses, the metro network being the obvious substitute.

LU claims that each weekday, some three and a half to four million people ride on the Tube. Even the LU upgrade plan, rumoured to be valued at over GBP 15bn, and aiming to increase capacity of the Underground by 30 per cent could not come close to dealing with the Olympic crush. Even Crossrail, another GBP 15bn and another claimed 10 per cent capacity increase doesn't add up to a system that can cope with the Olympics.

Speaking last April, an LU spokesman told the BBC that passenger numbers had increased 40 per cent in 15 years. So it will be some time before we see Olympic passenger numbers as a daily occurrence, but not forever.

The Olympics should be a wakeup call. These long-term upgrade projects are impressive in scope, terrifying in cost, but the numbers show they don't go far enough.

London's infrastructure is fragile. The *T&T* team made the 'error' of returning to London from WTC Bangkok during peak hours. The platform at Paddington Station was a dangerously crowded brawl to get onto the train, and with suitcases travel was impossible. This was in May.

The ancient and often inefficiently laid out infrastructure beneath old cities makes it difficult and costly to upgrade. At least compared to megacities in the developing world, which can learn from the mistakes of cities like London and plan underground space.

The British Prime Minister released a statement at the time of writing to say the games are a chance to show that "Britain can deliver". With deep tunnels the only solution to overcrowded surface and sub street London, it and other cities must show the investment, and let the tunnelling industry deliver.

Alex Conacher

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On the cover:
The latest extension to Prague Metro sees the return of TBMs after several decades of NATM dominance

BREAKTHROUGH SOLUTIONS FOR TOUGH JOBS AROUND THE WORLD

BRIGHTWATER TUNNELS BT4 + BT3-C
SEATTLE, WASHINGTON USA
RME 184 SE - Mixed Face 4.67 meter EPB TBM

- ✓ Initial drive of 21,000 ft. successfully completed (BT4).
- ✓ Difficult geological conditions and up to 5.1 bar pressure.
- ✓ Upgraded TBM for an additional drive of 10,000 ft. (BT3-C).
- ✓ Extremely abrasive ground and up to 7.3 bar pressure.
- ✓ Both drives completed ahead of schedule.
- ✓ Spectacular finish to a tough job and satisfied clients.



International Tunnelling Awards 2011
Tunnelling Contractor of the Year – WINNER: Jay Dee Coluccio Taisei & Jay Dee Coluccio JVs

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News in brief

Three killed in Shanghai tunnel crash

Three people died on Sunday 22 July after a BMW crashed into a walkway of Shanghai's Bung Tunnel in Huangpu district. It happened near the 3.8km tunnel's Wusongkou Road exit; the three passengers were thrown out of the car. The driver suffered only minor injuries. Police have said the case remains under investigation.

Funding approved for Hollywood pedestrian tunnel

Money to build a USD 22M tunnel connecting the North Hollywood Orange and Red Line stations was approved mid-July, the US Department of Transportation has announced. The project would create a 150ft (46m) underground passage. Construction could begin in March next year and end in Spring 2014.

Caterpillar to Sell Bucyrus

Caterpillar has signed an agreement to sell a distribution and support business to Hewitt Equipment Limited in the province of Quebec, Canada.

Up to USD 4bn sliced off Cross River Rail

AUSTRALIA

An expert panel appointed to review the Cross River Rail project has recommended that a version scaled back by as much as USD 4bn move ahead, a Queensland government official announced last month. Priority delivery of 'core' work followed by northern and southern surface works is now being considered.

The 'core' Cross River Rail project includes construction of two running tunnels from Yeerongpilly in the south to Victoria Park in the north, under the central business district and Brisbane River; four new underground stations at Woolloongabba, Boggo

Road, Albert Street and Roma Street; as well as connections to the existing northern and southern rail network.

In the announcement, Scott Emerson, the minister for transport and main roads said, "The panel concluded that the full Cross River Rail project was beyond the scope required to address the immediate rail capacity problem from the southern side of the river."

The new proposal, valued at nearly AUD 4.5bn (USD 4.5bn), no longer includes upgrades to other existing rail stations and removes plans to boost freight capacity south of the city. These changes are estimated to save between AUD 2bn (USD 2bn) and AUD

3.9bn (USD 3.9bn) compared with previous cost estimates. Earlier plans were valued up to AUD 8.3bn (USD 8.4bn) at one stage.

"The same result could be achieved by delivering the core of the original proposal, involving two tunnels between Yeerongpilly and Victoria Park," Emerson added.

Additional short-term solutions to increase capacity on the rail network are also being considered. This will ensure rail capacity in the inner city is maintained until Cross River Rail is delivered.

The department of transport and main roads is now preparing a submission for Cabinet to consider and will continue to seek funding from the Federal Government.

Workers rescued from Chinese tunnel after eight day ordeal

CHINA

Three Chinese railway workers who were trapped in a collapsed tunnel for more than a week were pulled to safety, local

media revealed last month. Around 400 rescue workers were called to the scene of the collapse to free the men. About 40m of the 2.625m Hongling Tunnel, an under-construction section of the

Hukun Railway, collapsed in Xinhua County, Hunan, on 30 June. The workers were kept alive with food and water lowered on a rope through ventilation tubes. The cause is being investigated.

Auckland's proposed CRL route identified

NEW ZEALAND

Auckland Transport last month unveiled the proposed route through the city centre for Auckland's City Rail Link (CRL) - from the Britomart terminus under Albert Street in the centre of the city to the suburb of Mt Eden.

The government agency is now making contact with directly affected landowners prior to seeking planning protection for the route. The CRL will be built in two

3.5km long, twin tunnels up to 45m below the city. As much as possible, the project will be built below city streets to reduce the effects on property owners and city heritage buildings.

Planning and property acquisition will take several years, in which time the Auckland Council will try to persuade the government to share the USD 1.93bn cost of the project. Property purchases will begin in two years.

Norwegian 4.8km rail tunnel awarded

NORWAY

NCC Construction Norway has been awarded a USD 170M contract to build a 4.8km rail tunnel between Larvik and Porsgrunn, about 150km southwest of Oslo. Work is scheduled to start in August 2012 and is expected to be completed in June 2016.

The contract was awarded by Norwegian national rail administration, Jernbaneverket.

Evacuation tunnels between Larvik and Porsgrunn will also be part of this construction assignment, bringing the total tunnelling work to 8.8km.

"This method of procurement, which involves the evaluation of several variables, such as organisation, resources and expertise, is something we welcome and believe benefits all parties," says Hakon Tjomsland, regional director at NCC Construction Norway.

Ottawa Light Rail Transit project receives approval

CANADA

The Ottawa Light Rail Transit (OLRT) project, estimated to cost CAD 2.1bn (USD 2bn), has received environmental assessment approval, a spokesman for the City of Ottawa announced last month.

Work to achieve environmental assessment approval began in March 2010. "With this announcement the federal government now joins the provincial government, which granted its environmental assessment approval in August

2010," the city spokesman said.

"This project is the largest, most complex infrastructure project in the city's history and we have achieved a very important milestone," said Mayor Jim Watson. "The federal government's endorsement of our approach is a critical step forward for us as we move towards finishing the RFP and selecting the team that will build this project."

The OLRT project is currently in the request-for-proposals phase of the procurement process. Three consortia - Ottawa Transit Partners, Rideau Transit Group

and Rideau Transit Partners - were shortlisted to bid on the project and council is scheduled to approve the winner in late 2012. Construction is expected to start in early 2013.

The light rail line will extend 12.5km, from the Tunney's Pasture federal government complex in the west to Blair Station in the east, at The Gloucester Centre near Blair Road and The Queensway. The downtown portion includes a 3.2km-long tunnel. It will have a total of 13 stations.

The project is expected to be completed by the end of 2017.

Tampere road tunnel contract to relieve congestion

FINLAND

The Finnish Transport Agency has awarded a EUR 185M (USD 227M) contract to develop a new tunnel in the city of Tampere, southern Finland, it was announced last month. A

consortium led by Finnish contractor Lemminkäinen won the contract. The contract has been awarded for the first stage of the VT12 Tampere tunnel project. During the current development phase, which will last around one year, an implementation plan and

target costs and other goals will be drawn up for the project's execution. The construction of the tunnel is scheduled to begin late next year and will be based on a separate contract.

The project is planned to ease congestion on Rantavayla road.

Tunnelling set to start on Chennai Metro project

INDIA

Tunnelling work at the Nehru Park site of Chennai Metro in southeast India was set to start as T&T went to press.

The two 5.8m TBMs imported from China have been assembled for the Egmore to Tirumangalam part of the project.

The TBMs will be positioned 9m below road level. Tunnelling will begin at Nehru Park, near Pachaiyappa's College, and proceed towards Egmore.

The second machine will be launched a month after the launch of the first.

A total of 11 TBMs are to be used for the construction of the city's underground metro network. Larsen and Toubro are the contractors for the project.

Phase One of the Chennai Metro project has been 'tentatively' scheduled for completion in the 2014-2015 financial year. Final approval for the project was granted in January 2009 by the Indian government.

Performance monitoring training course announced

GREAT BRITAIN

A two-day field monitoring training course will be launched next month.

The course, organised by University College London and Itmsoil is designed to provide practicing engineers with a sound understanding of monitoring in civil engineering.

The two day course takes place on 13 and 14 September and features a plethora of renowned speakers, including executive

News in brief

▼ **Glaswegian metro makeover approved**
Some USD 2M improvement works to a section of the Glasgow metro has been approved by Strathclyde Partnership for Transport. This section of work will be completed by spring 2013. Balvac has been awarded the contract to execute works.

▼ **Boy killed after sand tunnel collapse in New Jersey**
A 12-year-old boy who was rushed to hospital on the 17 June after a sand tunnel he was digging collapsed on him, died in the intensive care unit of Monmouth Medical Center one day later. According to a 2007 report in the New England Journal of Medicine, deaths from sand tunnels are not uncommon and there were 31 over a 20-year span.

▼ **Environment freezes Indian tunnel budget**
A budget of INR 676M (USD 12M) allocated for the construction of a tunnel under the Bheri-Babai Diversion Project has been halted. The budget has been frozen as an old design based on drill and blast has to be changed due environmental impact.

Queensland's Airport Link tunnel opens

AUSTRALIA

Airportlink M7, Australia's longest road tunnel, was officially opened to traffic last month following an extension of time. The 15km tunnel is part of an AUD 4.8bn (USD 4.9bn) investment in new transport infrastructure in Brisbane, Queensland.

Leighton Group's Thiess John Holland joint venture project team

designed and constructed the project, which took four years to complete. The tunnel was scheduled to open on 30 June 2012; the delay in opening the Airport Link tunnel cost its builder AUD 22.4M (USD 23M) in fines. In May 2012, the company pushed back the tunnel completion date and named August 20 as the likely opening date, which was missed by a few days.

"The project team managed to

deliver one of Australia's largest infrastructure projects within a few days of its contractual completion date - despite the significantly increased quantities, weather interruptions and a number of other challenges," said Hamish Tyrwhitt, CEO of Leighton Holdings. "Airportlink M7 will be transformational for Brisbane. It will substantially improve the road network to make it more reliable and safe for motorists."

Machine ordered for Moscow metro

RUSSIA

A 6.6m diameter EPBM has been ordered for the construction of one of the principle sections of the second circular line for the Moscow metro system. French designer and manufacturer NFM Technologies was awarded the contract.

The TBM, built on behalf of SMU Engeocom, will excavate a twin tube tunnel through geology

that is mainly limestone, clay and sand. The tunnel will link the 'Khodynskoe Pole' and 'Delovoy tsentr' stations to the north west of the city, over 6.2km in total, with two intermediate stations at 2km intervals.

The machine is to be manufactured by NFM's workshops in Le Creusot, with delivery scheduled for towards the

end of 2012.

The line is part of a programme drawn up by the Moscow authorities to increase their metro coverage by more than 70km. It will link in with several radial lines, reducing pressure on the first circular line built in the 1930s.

The Moscow metro is the world's second most heavily used metro system.

Below: An NFM Technologies TBM has been ordered for the metro



Viacheslav Lopatin

JICA supports India's Western Ghats tunnels

INDIA

The Karnataka government in southwest India is planning to build five tunnels through the Western Ghats at a cost of INR 48bn (USD 8.8M). An expert group from the Japan International Cooperation Agency (JICA) has submitted a report to the government on the construction of an expressway along National

Highway 48 connecting Bangalore and Mangalore.

Under the JICA proposal, the 18.5km stretch will include five tunnels. The project, to be built over six years, is expected to reduce the commuting time from three hours to less than half an hour. The road will also improve connectivity to the New Mangalore Port. The project is intended open the national highways between

Bangalore and the port city of Mangalore up to motor vehicles. The current 30km road from Sakleshpur to Mangalore climbs over the Shirdi Ghat section of the Western Ghats, which is largely inaccessible by car.

The government took the tunnel approach after it failed to receive environment clearances for converting the stretch into a four-lane highway.

News in brief

▼ **Rhode Island awarded USD 1.2M transit grant**
The Rhode Island Public Transit Authority (RIPTA) will receive USD 1.2M in federal transit improvement grants, it was announced last month. Some USD 820,000 has been awarded from the Federal Transit Administration to renovate the East Side Tunnel. This will be the first major renovation to the two-lane, 1,800ft (549m) East Side Tunnel in 20 years. The funds will also be used to upgrade the east and west portals.

Rescue, rebuild and reuse



AUSTRALIA

An abandoned 260t crane has been rescued and recommissioned to build and dismantle the TBMs on the Legacy Way tunnel in Brisbane, Australia. Eilbeck Cranes Ingleburn originally supplied the crane for the CLEM Seven tunnel project in Brisbane.

Legacy Way contractor Transcity JV discovered the crane was sitting unused at the airport and approached Eilbeck Cranes

Left: The Legacy Way machine being assembled for the project by the recommissioned crane

Brisbane to recommission the crane. To prepare it to reenter the field of duty, Eilbeck Cranes Brisbane service manager Bren Woodward led a service team responsible for making minor structural adjustments to the machine.

The work was completed in the first week of June and the crane was onsite last month.

Transcity is a joint venture of Australian company BMD Constructions, Italian outfit Ghella and Spanish firm Acciona.

It was awarded the construction contract for two parallel tunnels on Legacy Way in Toowong, a Brisbane suburb.

Chilean desert tunnel awarded

CHILE

A new tunnelling project at the world's largest copper mine in the Chuquibambilla in the Chilean deserts, worth about EUR 100M (USD 123M) has been awarded, a spokesman announced last month.

Austrian construction company Strabag will build several tunnels to improve the infrastructure of the mine. The company will work with its subsidiary Zublín Chile and a local partner. It will be executed over a period of three years.

"In markets outside of Europe, we work on selective projects that require special technical know-how," said Dr Hans Peter Haselsteiner, CEO of Strabag. "This is especially true for tunnelling."

Both the mine and the nearest city of Calama are located in one of the driest places on Earth, in Chile's Atacama Desert, approximately 1,250km north of the capital Santiago.

The client is Chile-based Codelco, the largest copper-producing company in the world.

Fresh awards for Gothenburg rail scheme

SWEDEN

The Haga underground station contract was last month awarded for the West Link rail project in Gothenburg, Sweden. The contract was awarded to Ramboll and consortium partner Vectura. The commission has a value of approximately EUR 9M (USD 10.9M).

The new underground system will alleviate pressure on the city's road and overland rail networks as

well as improve access to the centre of Gothenburg.

Ramboll's responsibilities cover construction, electrical engineering, wastewater, water resources management, urban development, traffic planning and other environmental issues.

Early last month a Ramboll spokesman announced that the company had been awarded a EUR 11M (USD 13.3M) contract on the West Link project.

The project scope includes

route planning for the line.

"To be selected on both the route planning and underground station elements of this important infrastructure project is a real honour and a great achievement," said Borje Eriksson, division manager for Ramboll. "This complex initiative demands a truly holistic approach and we will be drawing on multidisciplinary expertise from across the company to deliver the very best solution for the customer."

CLEVER CONVEYING. PRAGUE, CZECH REPUBLIC.



Two phases. One solution.

Prague/Czech Republic. As specialist in conveyor belt systems, H+E Logistik GmbH supplied the equipment required for the new construction of two tunnel tubes with a length of 5,300 m each for the new Metro line expansion from the airport to the northwestern areas of Prague. This equipment guaranteed rapid tunneling progress. The project was divided into two project phases to save costs and time, therefore the system was designed for both phases. In the first phase the system included two vertical belt storages installed on the surface 20 m above the tunnel to realize the continuously extendable tunnel belt. A steady adit conveyor conveyed the muck to the surface. In project phase two a clever position of the belt storage in combination with a belt deflection station saved space. Thus costs and maintenance work could be saved. Typically H+E.

The bare facts:

- Tunnel diameter: 6.05 m
- Conveyor length: 2 x 2650 m
- Belt width: 650 mm/800 mm (adit)
- Capacity: 2 x 400 t/h / 1 x 800 t/h
- Installed power: 2 x 160 kW per tunnel / 1 x 160 kW (adit)
- Belt storage capacity: 2 x 400 m/vertical
- TBM: 2 x EPB shield
- Installation: 2011
- Contractor: Metrostav



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Design contract awarded on Santiago metro

CHILE

An international consortium has been awarded a contract to provide engineering consulting services for the civil works on Lines Three and Six of the Metro System in Santiago, Chile. A consortium of Arcadis, ARA WorleyParsons and Sener Ingeniería y Sistemas was awarded the 12 month, USD 9M contract last month.

The project scope includes

basic engineering for the civil works for the two lines, to generate all the information necessary for Metro to define the subsequent detailed engineering and construction contracts.

The project is part of the Urban Transport Investment Plan of Santiago through which the metro will expand its current 100km network to 140km including two new lines. Line Three will have a total length of 15.4km and 10 stations. Line Six will have a total

length of 22.1km and 18 stations.

"The large number of high-quality professionals at the disposal of Arcadis and the consortium as a whole, including the experience, knowledge and efficiency needed for these types of highly complex projects, meant that the consortium is ideally placed to satisfy all of the client's needs, both in terms of quality and meeting time schedules," said Hernan Bezamat, CEO of the Chilean arm of Arcadis.

Historic London subway given Crossrail grouting role

GREAT BRITAIN

The Kingsway Tram Tunnel, a historic subway in London, UK that has been abandoned for the last 60 years, will be temporarily re-used for Crossrail, it was revealed last month.

Crossrail's western tunnels contractor BFK is making use of the tram tunnel underneath

Kingsway that once took passengers from Holborn to Waterloo Bridge, to build an 8m deep, 5m wide, grout shaft below the floor of the tunnel. This will protect nearby buildings from any potential ground movement when Crossrail's TBMs reach that area in 2013.

"The Kingsway Tram Tunnel has played a fascinating and unique

role in London's transport history," said Keith Sibley, Crossrail area director. "Now it will play a vital part in helping prepare the ground for the city's most ambitious transport project to date. As the tunnel is a Grade II listed structure, Crossrail will return the Camden section of the tram tunnel to its prior condition when the works are completed."

Queen Elizabeth opens new Tyne Tunnel

GREAT BRITAIN

The Queen, accompanied by The Duke of Edinburgh, opened the new Tyne Crossing in

Jarrow, Great Britain last month, 45 years after opening the old tunnel in 1967. The Royal party visited the north side of the tunnel and met Tyne Tunnel staff; the

Queen gave a speech and unveiled a plaque to mark the official opening of the tunnel. "Now the project is complete, I would like to congratulate all those who have played a part," the Queen said.

Main construction work for the second vehicle tunnel under the Tyne began in October 2008 and opened in November 2011.

The tunnel provides a transport link beneath the River Tyne adjacent to the original, tunnel that was built in 1967.

Left: Opening the new tunnel 45 years after the old



News in brief

Parsons Brinckerhoff transport appointment
Engineering and management firm, Parsons Brinckerhoff, has appointed a new principal consultant for its Washington DC office. Nathan Macek will expand the consulting practice in transport development and finance.

Niagara nears completion
The USD 1.57 Niagara Tunnel Project is due to open in December 2013, it was announced in mid-July. The tunnel was originally due for completion in 2009, but that date was pushed back when the TBM hit tough conditions along the 10km route.

Work begins to fix Tennessee Pass hole

USA

Repair work costing USD 1.5M on a 100ft (30m) hole, caused by a collapsed century-old railroad tunnel under the US Highway 24 on Tennessee Pass, has begun.

Hayward Baker won a roughly USD 830,000 contract to do the repairs. Works on the project started last month.

The hole opened on 9 July when the soil gave way above the abandoned, partially collapsed railroad tunnel, which has been disused since the 1950s. Colorado Department of Transportation thought the tunnel had settled and built over it many years ago.

The collapsed tunnel was the first tunnel built under Tennessee Pass. Union Pacific replaced the tunnel with another one about 550m away. The replacement tunnel is still in use and was not damaged in the collapse.

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Tunnelling begins on Mumbai water project

INDIA

Excavation of India's 8.3km Mumbai Water Tunnel began last month.

The TBM had bored over 320m as of 4 July 2012.

The tunnel is being bored by a Robbins 6.25m main beam TBM.

Unity-IVRCL JV is the contractor for the basalt rock tunnel, which will alleviate the

city's current leakage problems from its ageing lines and provide the inhabitants with a consistent flow of clean drinking water.

The TBM was launched from a 109m deep shaft and its launching sequence included an initial start-up excavation of 50m with vital back-up decks connected to the TBM using cables.

The first bore began in March and upon completion the decks

were lowered and a continuous conveyor system was installed for muck haulage and storage.

"Robbins has made an outstanding effort during the excavation without many difficulties, which speaks to their knowledge and team spirit," V D Shama, director of operations at India-based Unity Infrastructures said following the initial works and the excavation.

Bosphorus Strait crossing tunnel design contract award

TURKEY

A US-based firm has been selected as independent design verifier on the Istanbul Strait Crossing tunnel project in Turkey, which will connect the European and Asian sides of the city by a road tunnel. The project will be delivered by public-private partnership procurement, HNTB stated last month.

HNTB's scope of work will include performing design review and Category Three independent

check of the design to verify that it is done correctly and in accordance with the project design criteria, owner's requirements, and international codes and standards. The team will review and verify the project geotechnical parameters and perform analyses for the bored tunnel, NATM tunnels, cross passages, transition boxes and cut and cover structures.

The tunnel is approximately 5.4km in length and includes 3.8km of 44-foot-diameter

(13.4m), single-bore, double-deck TBM tunnel under the Bosphorus Strait; twin bored complex geometry tunnels using New Austrian Tunneling Method; cross passages; transition structures, cut-and-cover and U-shape approaches; portal structures, toll plazas, ventilation facilities, tunnel control and other support facilities and multiple complex structures, interchanges and facilities on both sides of the strait.

Anticipated completion date for the tunnel is 2016.

New boring system for Oz

AUSTRALIA

A new tunnel boring system, the Mobile Tunnel Miner (MTB), is due to arrive at Northparkes Cooper Mine in southeast Australia this month ready for its use in underground mines. The machine has been developed by Aker Wirth and Rio Tinto, one of the world's largest mining companies, for Rio Tinto's 'Mine of the Future' programme. It left Aker Wirth's production facility near Dusseldorf, Germany, late

last month.

The machine has been developed for hard rock tunnelling and mining; using undercutter technology it is efficient with tunnelling in hard rock of up to 300MPa UCS. It is also able to cut rectangular or horseshoe-shaped tunnel cross-sections, in addition to circular tunnels, of up to 6m bore diameter.

"We will revolutionise safety and efficiency in mining with the new MTM," said Einar Bronlund, CEO of Aker Wirth.

Central-Wan Chai Bypass tender announced

HONG KONG

Hong Kong's Highway Department is inviting tenders for the construction contract for a tunnelled section of the Central-Wan Chai Bypass, it was announced last month. The works are expected to begin in

News in brief

▼ Dorset tunnel car deaths

Two people have been found dead in a car buried under 700t of mud at a road tunnel entrance in Dorset, UK. The man and woman were discovered in the car 10 days after being trapped under a landslide at Beaminstor Tunnel. They were found on 16 July. The tunnel had been closed since 7 July when a landslide was caused by heavy overnight rain.

▼ Report slams California's Bay Delta Conservation Plan

The heavily contested Bay Delta Conservation Plan is not economically justified, according to an independent cost-benefit analysis of the proposed project by the Business Forecasting Center at the University of the Pacific in Stockton would be USD 7bn higher than the potential benefits.

▼ Springfield rehab contract

Springfield, Missouri has awarded a USD 6.3M contract for the rehabilitation of over 35km of sewer pipelines. The contract, awarded to Insituform Technologies, is part of a four year improvement plan valued at up to USD 30M to eliminate pipeline filtration issues.


March 2013 for completion in January 2017.

Work comprises construction of a section of tunnel in the Causeway Bay typhoon shelter including the associated temporary reclamation, and the subsequent removal of the temporary reclamation after completion of the tunnel. The scheme also includes the Slip Road Eight tunnel structure beneath the existing Victoria Park Road as well as improvements to the existing facilities, and extension of a pedestrian subway and the associated roadworks.

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APPGUS merges with APPGI

The UK's All Party Parliamentary Group on Underground Space (APPGUS) has merged with the All Party Parliamentary Group on Infrastructure (APPGI). The announcement was made during the APPGI annual general meeting in July, and by not holding an APPGUS AGM, the latter was dissolved. The merger will allow the two All-Party Parliamentary Groups (APPG) to combine their loyal politicians, giving a greater reach across the UK's political system. It also sharpens the focus of government onto the one APPG, and lends the interest and financial clout that tunnelling generates to the larger parliamentary group.

Helen Natrass, chair of the BTS political lobby group and steering group for APPGUS said, "In the last few years, we have seen tunnelling becoming increasingly high profile in the infrastructure construction sector. The infrastructure APPG has wanted to take people to see tunnels, and we have seen a crossover.

"We do not want to step on each other's toes and it can give the wrong message of: 'we do tunnelling, which is sort of infrastructure but separate.'"

Nick Raynsford MP, chair of both groups added, "I welcome the decision and I am sure it will

help maintain an effective group with a real interest in tunnelling and infrastructure."

APPGUS was created in October 2002 and it was a group of Parliamentarians that included both MPs and Lords with an interest in the subject, as well as an interest in the aims of the British Tunnelling Society (BTS)'s political lobby group.

The BTS lobby group, a subcommittee of the society, was instrumental in setting up APPGUS. Following this move the ICE set up the infrastructure APPG. Both parties will be part of the steering group for the newly merged APG, with three representatives from the Institution of Civil Engineers (ICE) and two from the BTS.

The ICE representatives are: Graham Sibley, ICE head of communications and marketing with assistance from Joanna Gonet and Gloria Liu. For the BTS are Helen Natrass and a representative that had not been chosen as *T&T* went to press.

The aim of the BTS with APPGUS was to allow the society to influence the decision-making process in the UK Government. Natrass said, "We have lobbied primarily through APPGUS. This allows us to target decision makers. Through them we have approached bodies such as the Treasury and Transport Ministry."



Above: Helen Natrass heads the BTS's political lobbying activities

When the issue is serious enough to warrant it, a letter written by a learned society to an MP requires a 'proper response' from said MP.

Natrass added, "We have also been able to inform Parliament on projects, such as the Thames Tideway sewer project and the

storage of spent nuclear waste. These are concerns that they do not come across in their daily activities."

In addition to its usual activities to further tunnelling, the newly merged group will enable the BTS to contribute to ICE policy documents sent to parliament.

The BTS has enjoyed strong links with the International Tunnelling Association (ITA), but no international political lobbying activities have been undertaken. The BTS has been in contact with other learned societies.

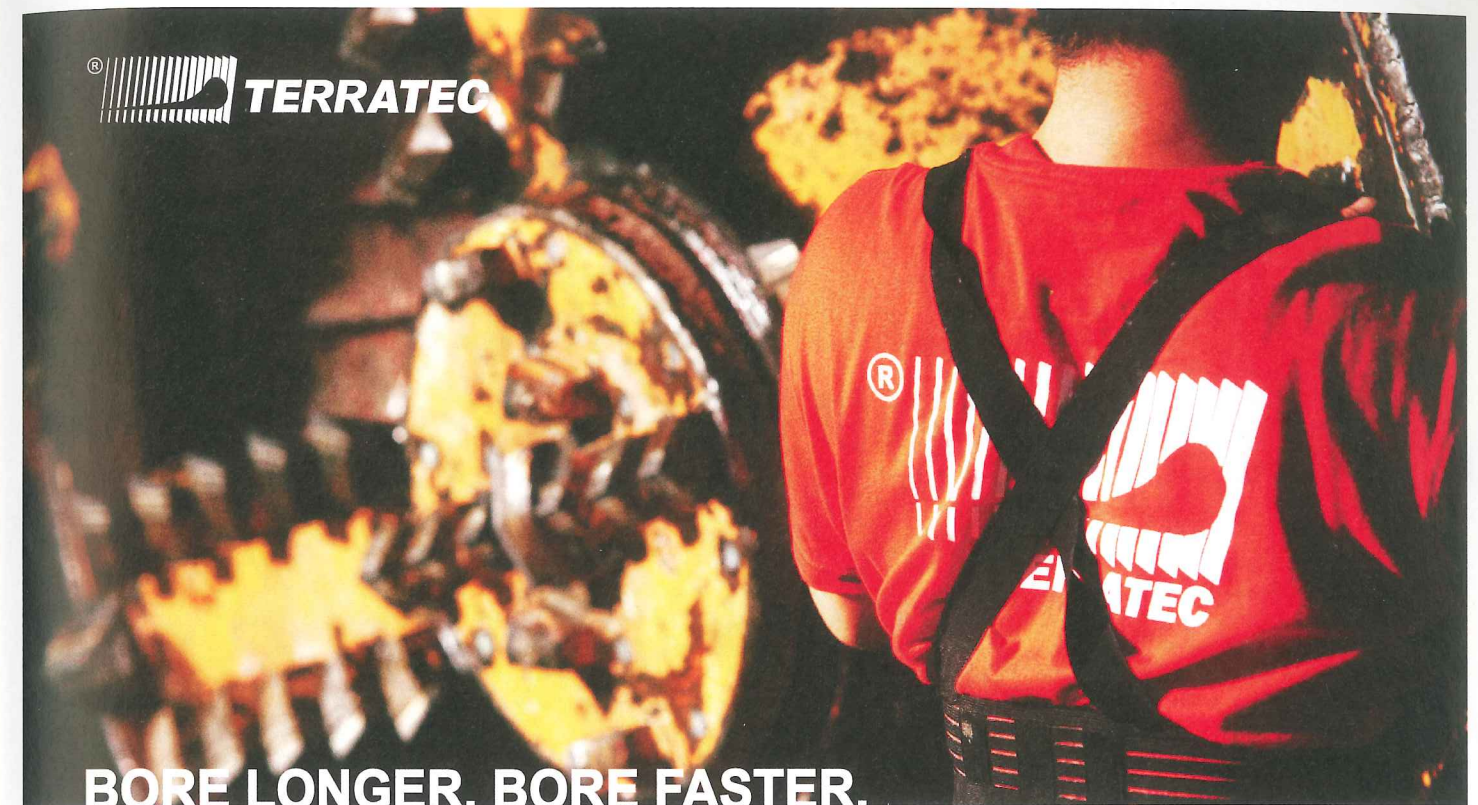
For further details, contact Helen Natrass or the BTS.

Alex Conacher

APPGs and APPGUS

All-Party Parliamentary Groups (APPGs) are informal cross-party groups that have no official status within Parliament. They are essentially run by and for Members of the Commons and Lords, although many groups involve individuals and organisations from outside Parliament in their administration and activities.

APGUS has members from across politics. "A number are genuinely interested in infrastructure and keeping projects on track," said Natrass. "Interestingly this seems irrespective of party politics. Another element just like visiting tunnels. Then there is a middle group who have a local interest."



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Expanding the core niche with people

In June Normet announced that it had acquired the remaining 40 per cent of the shares of TAM International that it did not already own (see *T&T* July 2012, p.10), thus fully integrating the global machinery business of Normet with the construction materials business of TAM.

In an exclusive interview with *T&T*, Tom Melby, president of the Normet Group and managing director of Normet International, emphasised that the expanding group will stick to its core marketing of underground construction and mining, with the emphasis on rock support.

Explaining the development of the Normet-TAM merger Melby said, "When I joined Normet it was a traditional manufacturer of equipment for mining and underground construction, with a leading position in sprayed concrete equipment worldwide, but it needed expertise in concrete technology and application to offer the full process know how to customers. I came to build up the global network of Normet, mainly to provide full sales, service and process solutions in rock support to customers, based on my 30 years of experience."



Above: Normet's Tom Melby

Normet expanded its equipment sales and support from 2008 with new establishments in 18 countries. "Normet already covered Russia and Kazakhstan, and we opened up new entities in China, Australia, Indonesia, India, Chile, Peru, Brazil, Mongolia, USA and Canada as well as central Europe. Recently we opened a new company in Mexico, an interesting market, and also a company in South Africa."

"Many of my former colleagues joined me in the Normet group or at TAM, and I also knew many

other people at TAM," says Melby, "so it was a natural reunion. The integration is more-or-less done in operational terms.

Initially TAM had expanded internationally at the same time as Normet did, mainly in southeast Asia including Singapore and Hong Kong, as well as Australia.

However TAM ran out of resources for further expansion on the scale required.

"TAM had a virtual 'palace' of products for construction and mining," continued Melby, "so it gave us the right balance of 'lines' when we took over to complete the picture in a very compatible niche market. We have no intention to develop general construction nor markets other than geotechnical, waterproofing [...] tunnelling and mining."

When asked about expansion into other technologies as well as geographical markets, Melby said, "We already have a pretty extensive offering. We are already into soil conditioning and backfill products for TBM operation. We do, however, intend to develop more with injection products and anchoring (rock-bolt bonding) for ground support.

"We are also working hard on a new generation of alkali-free concrete accelerators."

Despite the promotion of passive fire protection by some competitors, Melby is not so keen. "I think interest has gone down a little bit, especially with the development of alternative active fire protection such as water-mist systems," he claims. "But we do have good knowledge of the subject in house if the market needs it."

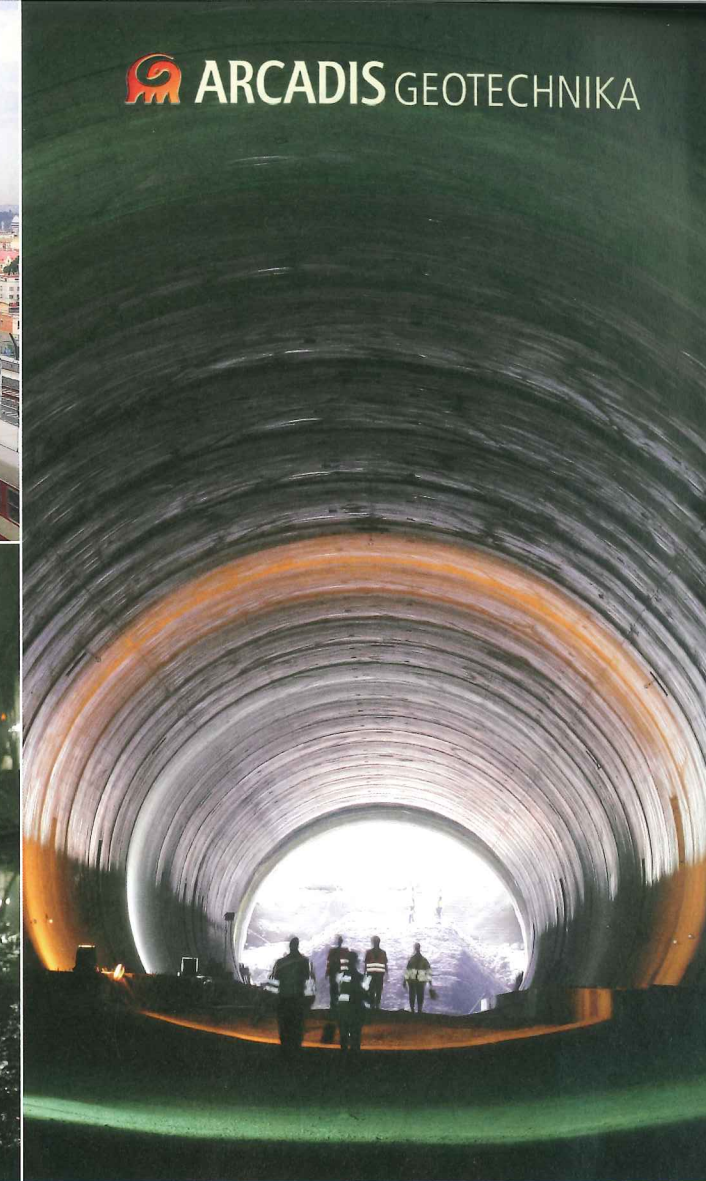
Normet's purchase of Essverk Berg last year not only gave it a physical presence in Sweden, also

covering Norway, but also increased its range of equipment technologies to include waterproofing membrane handling, and the handling and erection of segmental lining, as well as other specialist equipment.

Contrary to 'accepted wisdom', Melby does not believe that the huge potential markets of China and India necessarily want less sophisticated products. "I believe China and India are more ready to work with up-to-date systems than some European countries. There is a drive for efficiency and to come close to European standards that demands more productive equipment and materials. But we need to offer training and skills to support this drive. We need our people on a project that can support more sophisticated equipment, and we have already had some success in this with our operations in China and India. Most of our sales are in the high-end of our products."

"I believe our competitive edge is to be close to our customers globally," said Melby, "and that means an emphasis on people. We now have establishments in 36 locations and have recruited 600 staff in the last three years. Some 500 of our staff are in customer-facing roles involved in service and trouble-shooting. We are a private company and so can take very fast decisions in an entrepreneurial spirit. This allows us to work very quickly and react to customers' needs. Normet's growth during expansion to 2010 has been around 30 per cent; in 2010 it was 45 per cent, and we expect growth in 2012 to be another 45 per cent. I am very optimistic for the future whatever turn our markets take."

Maurice Jones



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Below: Normet Spraymec 8100 VC 1 in operation



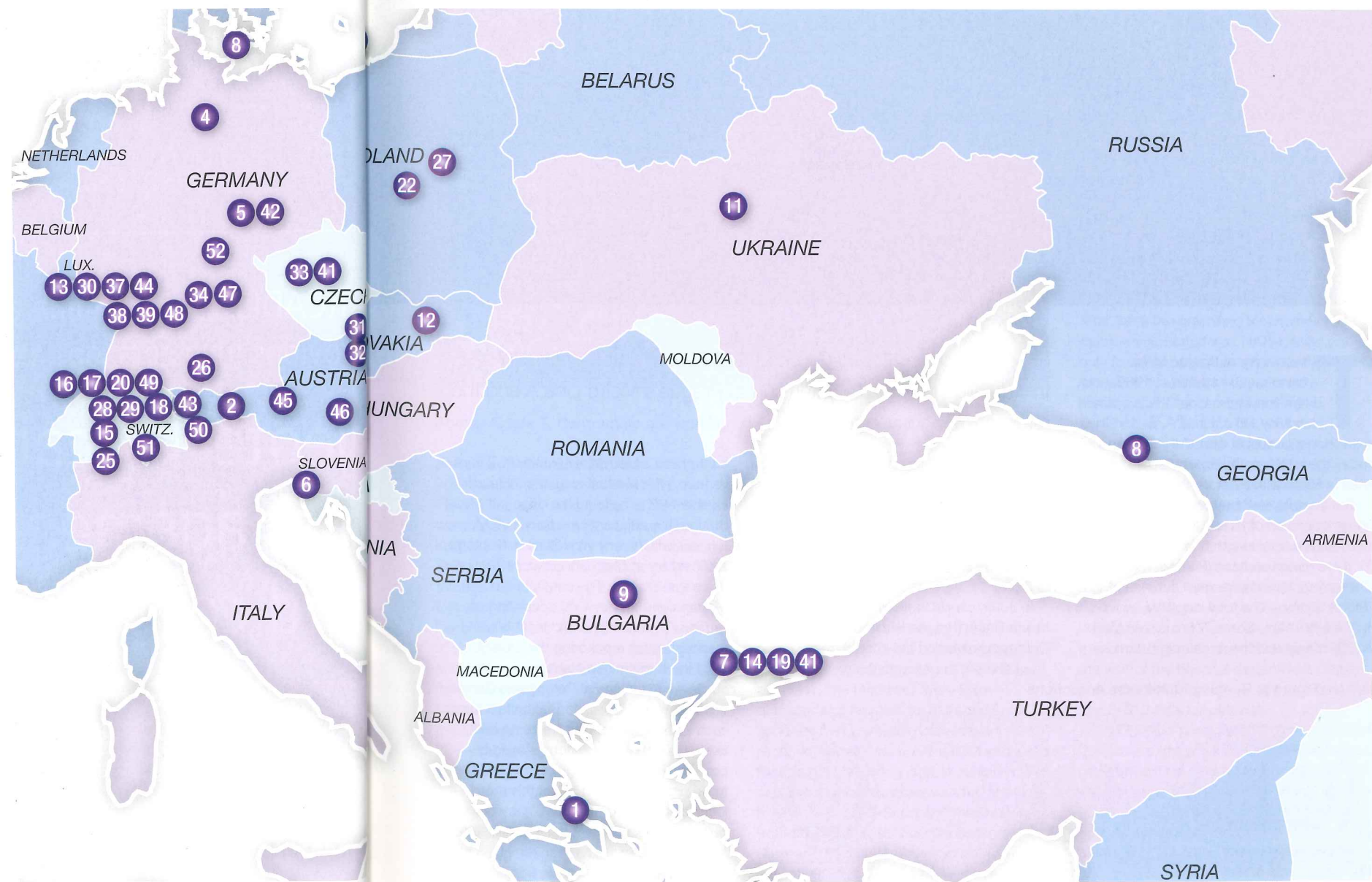


European links connect the dots

On track to break its own record for constructing the world's longest transport tunnel, albeit over ten years from now, Central and Eastern European tunnelling enjoys a boom in the construction of transport infrastructure. International projects such as the TEN-T networks, with sections linking north and south, east and west are driving demand for tunnels. Alex Conacher explores

- | | |
|--|--|
| 1) Athens Metro Line Two extension | 29) Morschacher motorway tunnel |
| 2) Brenner base tunnel | 30) New Kaiser Wilhelm rail tunnel |
| 3) Lainzer tunnel | 31) Sankt Polten Raingruben rail tunnel |
| 4) Hamburg X-Fel X-ray laser tunnel | 32) Stierschweiffeld rail tunnel |
| 5) Bibra tunnel | 33) Malovanka-Pelc Tyrolka tunnel |
| 6) Markovec tunnel | 34) Heckenstallerstrasse road tunnel |
| 7) Avrasaya development | 35) Dnieper River road crossing |
| 8) Fehmarnbelt | 36) Kyivavtodvor-Livobierzna Station to Victory Square road tunnel |
| 9) Shipka peak tunnel | 37) Stuttgart HSR airport tunnel |
| 10) Slovak Sucharski tunnel | 38) Ober/Unterturkheim HSR tunnel |
| 11) New Beskyd tunnel development | 39) Filder HSR tunnel |
| 12) Paludza railway tunnel | 40) Prague metro |
| 13) Heslach road tunnel | 41) Marmaray rail tunnel |
| 14) Bosphorus rail crossing | 42) Leipzig City rail tunnel |
| 15) Rosshausen-Mauss rail renovation | 43) Arlberg motorway escape tunnel |
| 16) Choindez de tunnel road | 44) Pforzheim rail tunnel |
| 17) Belchen motorway tunnel refurbishment | 45) Wiesling to Jenbach rail tunnel |
| 18) Kublis road bypass tunnel | 46) Asfinag to Gleinalm road tunnel expansion |
| 19) Istanbul Strait road crossing | 47) Garmisch road tunnel |
| 20) Tunnel de Bure road | 48) Riederwald road tunnel |
| 21) Konigsdorf road tunnel | 49) Astra to Graiteray road tunnel |
| 22) Lodz Fabryczna to Lodz Kaliska rail tunnel | 50) Asfinag to Tauern road tunnel |
| 23) Rudersdorf road tunnel | 51) Ceneri base tunnel |
| 24) Speltenbach road tunnel | 52) Grossbreitenbach Silberberg road tunnel |
| 25) Eyholz road tunnel | |
| 26) Auerberg road tunnel | |
| 27) Warsaw Metro Line Two | |
| 28) Sisikoner motorway tunnel | |

Additional material by timetric.com and www.construction-ic.com



As the Eurozone financial and political sectors face another crunch moment to see if Greece has been austere enough to deserve its final round of bailout loans, tunnelling, while competitive, is still strong.

Lacking the slew of hydropower and water transfer projects that have dominated recent *T&T* regional project maps in India and Africa, the market in Central and Eastern Europe is dominated almost entirely by a demand for transport infrastructure.

Megaprojects such as the Brenner Base Tunnel (see page 56) push the boundaries in terms of scale, in this case increasing the record length for a transport tunnel from the

neighbouring Gotthard Base Tunnel's 57km to a full 64km. Though the total length of associated tunnelling is claimed by the client to be around 200km.

It appears that, as might be expected, the Alps constitute the most active centre for tunnelling in the region, with other localised areas of activity, such as the Bosphorus Strait.

A new road tunnel crossing design contract was awarded for this bottleneck last month (see page 12).

A report by *T&T* publisher World Market Intelligence's economic analysis arm Timetric highlighted the relatively recent entry of East European countries into the

European Union (EU) as a major driver of infrastructure growth. Collaborative, international funding being made available to projects, as well as an influx of foreign business to these regions have provided the means, and the requirement for infrastructure upgrades.

Aside from this, meeting EU standards for water and pollution provides further incentive for national governments.

Large scale projects are not very common in the far east of Europe, before reaching Russia, and the region lacks the present tunnelling boom of Central Europe and the UK. In this report, *T&T* explores the heart of Europe.

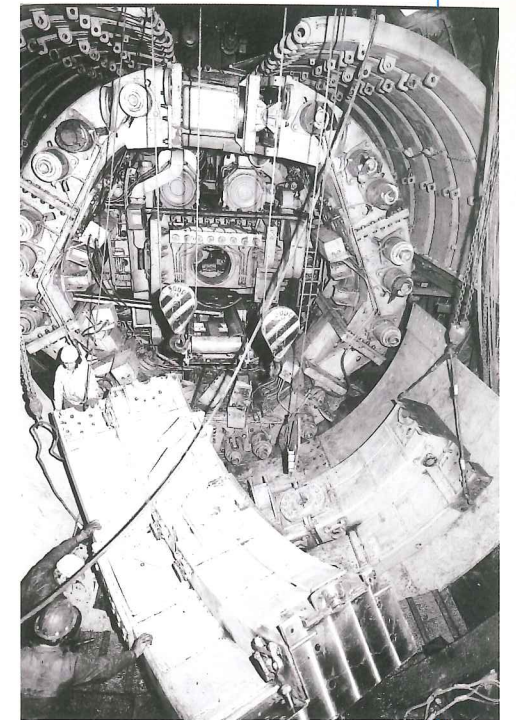


Prague Metro's return to TBMs



Left: Adela arriving to the one-vault Petřiny Station. Photos courtesy of contractor Metrostav

alignment. The geology is mainly characterised by clay shale of differing geological age, which makes up Prague's bedrock and in which many kilometres of tunnel have already been built. Besides the shale, at the start of excavation there are mixed face conditions with, for example, a sandstone layer in the upper part of the face and siltstone and claystone materials at the bottom. Under such conditions boring was frequently accompanied by quite large inflows of water that had collected on the impervious clayey layer. To the end of their drives the TBMs will be



Above: TBM in 1975 at Staroměstská Station, Line A

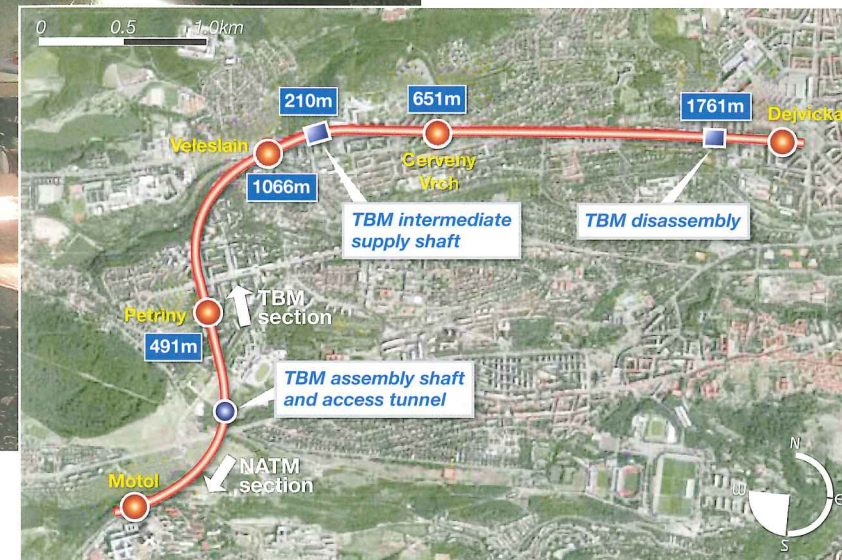
buildings. There were no excessive settlements and therefore no damage to the old buildings.

Modern TBM application

After 1989 the prevailing technology for metro construction was NATM, used not only for stations, but also for running tunnels. It took nearly 40 years to re-introduce TBM technology for metro construction. This time it is the latest TBM technology; Metrostav acquired a pair of identical EPBMs manufactured by Herrenknecht after contract award.

The machines started their journey not far from the Motol Hospital, which is the largest hospital in the country, and has large children's wards. Metrostav's management and Prague mayor Bohuslav Svoboda arranged for the children from the children's ward to name the two TBMs. The mayor made the choice of names during the visit of the hospital department. They named S-609 Tonda (equivalent to Tony) and S-610 Adela (Adelaide).

The EPBMs have a diameter of 6,050mm and are equipped with a 1,200kW hydraulic main drive. The TBM is 102m long and weighs approximately 680t. When tunnelling, 32 thrust cylinders (16 pairs) apply a nominal thrust force of about 39,000kN (340 bars). The cutting wheel is equipped for rotation in both directions. It is



Above: Figure 1, Contractors are working on the latest extension of Line A (V.A.)

pressure on contractors to keep the tight construction schedule. In May 2012 the TBM drives and construction of the stations were approximately half-way through, keeping on schedule for the 2014 opening. Side drifts allowing the passage of the TBM through the stations were driven first, followed later by excavation of top heading, bench and invert. The initial lining consists of shotcrete with steel mesh, lattice girders and bolting. The final lining will be cast after the waterproofing membrane is installed; in Veleslavín Station a sprayed waterproofing membrane is used, in all other sites, classic PE membrane with protective geotextile will be used.

Geology

The EPBMs have been designed to suit the prevailing geological conditions that have been predicted along the designed tunnel

challenged by stretches with deluvial deposits consisting of loamy-sandy soil, which are predicted along much of the tunnel alignment.

History of TBMs on the Prague Metro construction

The first use of TBMs on Metro construction goes back to the 1970s when two Soviet made TBMs bored running tunnels during construction of the first part of Line A. The machines were 5.8m diameter and featured an extruded concrete lining, where concrete was pumped from the rear of the TBM into a slip form to cast the lining. The extrusion was a popular method, being developed at the time in Japan and Germany. The machines bored the running tunnels under the Vltava River and also under the Prague Old Town, which has many significant historical

Ermin Stehlik and David Cyron of Czech contractor Metrostav give this detailed look at the extension to Prague's Metro Line A and the return to TBM driven tunnels

The history of Prague Metro construction started in 1966, and the first Metro Line C was opened in May 1974. Lines A, B, and their extensions were built over the years, and today the total length of metro operating lines is 59km with 57 stations.

Contractors are now working on the latest extension of Line A, known as V.A., which has a total length 6.1km (see Figure 1), three mined stations (Petřiny, Veleslavín, Červený vrch) and one open cut station (Motol Station). The total length of running tunnels is 9.1km. Some 700m is twin track NATM tunnel and the remaining 8.4km is

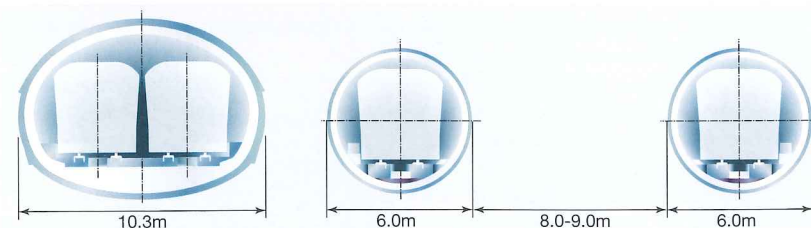
being constructed using two TBMs acquired by contractor Metrostav. Both machines are identical Herrenknecht EPBMs with the production numbers S-609 and S-610; shield diameter is 6m giving a finished segmental lining diameter of 5.3 to 5.8m.

In 2009, client Dopravní podnik hlavního města Prahy (Prague Public Transit Company) awarded the construction

contract to a Metrostav/Hochtief CZ joint venture, with Metrostav as the JV leader. Hochtief CZ is building the open cut Motol Station, the adjacent twin track NATM tunnel and Červený vrch Station. Subterra, a subsidiary of Metrostav, is constructing Veleslavín Station. The consultant is Metroprojekt Praha. A JV consisting of Arcadis Geotechnická and Inset is responsible for monitoring the project.

Of the three mined stations, two are single vault stations at Petřiny and Červený vrch, whereas Veleslavín Station is a three-vault station; all stations are being built using NATM. During various stages of construction the passage of the TBM has to be provided for. On top of this the logistic support for the TBM, namely the belt conveyor, segment transport system and other materials, have to remain in place for some considerable time. All of this puts

Below: Figure 2, Running tunnels cross sections





designed with an opening ratio of 30 per cent and fitted with 38 disc cutters (17-inch) of 100mm spacing, 64 cutting knives and eight buckets. Alternatively the cutter heads were fitted with ripper tools. Two hydraulic wear detection units are installed for the soft ground tools and buckets. Tail skin grouting used a two part system (see box).

Information and monitoring

The availability of actual data in real time is a basic requirement for optimal control of the tunnel driving process and risk minimisation. VMT supplied a modular and web-based multi-user IRIS (Integrated Risk and Information System). This system is combined with another VMT product, Tuis Navigation TBM Laser, and a segment documentation system (SDS) was used in segment production. To check the grouting procedure, a grout pressure sensor system (GPSS) for measuring the grout pressure behind the lining was used.

The system was vital during the TBM passage under sensitive areas, where strict settlement limits were set. In such cases, continuous information on settlement measured above the tunnel route was combined with all relevant operational data from the TBM to allow the development of sensitive tunnelling strategies and, in terms of risk avoidance, to continuously optimise the tunnel excavation.

Another database system used in the project is Barab, operated by Arcadis Geotechnika, in which mainly the settlements and extensometer measurements results are being shown.

Segments

The tunnel is lined with reinforced concrete segments. One 1.5m-long tunnel ring consists of five segments plus a key.

The geometrical design of the segments considers all loads including water pressure and soil conditions, as well as stresses arising from the construction of the tunnel.

The universal-ring, tapered on both sides, has an internal diameter of 5.3m and a thickness of 250mm. Herrenknecht Formwork supplied high-precision moulds. The segments are equipped with EPDM-gaskets and are bolted during installation in the circumferential and longitudinal joints.

The segments were produced by Doprastav in the Prefa precast factory in Senec, where in total over 32,000 segments will be produced.

TBM launch and route

Both TBMs started the more than 4km long journey in the purpose built shaft at Vypich site. The shaft lining consists of secant

Grouting

The two component grouting system was chosen, in line with global industry trends. Component A is a mixture of cement, bentonite, liquid retarding agent (CBS system from Mapei) and water. It is designed to be stable for 72 hours allowing transport via pipe system from the mixing plant on the surface to the TBM (with maximum distance 2.5km), taking into consideration all sorts of possible delays during the boring. Component B, sodium silicate, is only added in the TBM tail skin to enable gelling and later hardening of the grout.

Site arrangement for the two component grouting consists of three silos, one water tank, one container for additives, mixing plant and two pumps supplied by Hany. One silo is for bentonite, two are for cement. The capacity of each silo is 60t of powdery material.

After the end of the mixing procedure the mixture is pumped into the agitator, where component A can be stored for a period up to three days. From the agitator two grouting lines run through pumps down to both machines. When the quantity of component A in the storage tank on a TBM drops below a pre-set level, the pump is turned on and starts to automatically to pump component A from the agitator down to the tank on the backup.

The grouting line is composed of galvanised pipes with a length of 6m, and a diameter of 2.5 inches, connected together by couplings. These allow relatively easy and time efficient pipe extension, which has to be done periodically with the advance of a TBM.

A multi service vehicle is used to transport component B in 1,000 litre plastic containers.

During the initial construction stages teething problems with the sensitive two-component grouting were experienced, but successfully solved by 'fine tuning' both the mix design and the equipment. The most difficult part of the system as far as the cleaning is concerned, is the 1.2m section of the tail skin pipe from the mixing nozzle to the rear part of the tail skin. In this part, the mix of both components settles and adheres to the wall, despite automatic flushing by the system. To avoid cleaning of the outlet from the mixing nozzle to the end of the tail skin, the B component nozzle was moved towards the tail skin end. This was done by connecting the silicone hose to the existing nozzle and inserting it into the oval tail skin pipe for the distance around 1m.

drilled piles of 1,180mm diameter. The shaft internal diameter is 23.6m and depth is 32m. During construction the contractor, Zakladani staveb Praha (part of Metrostav Group), achieved extremely good results with a maximum deviation of 0.7 per cent, and with 70 per cent of piles drilled with deviation less than 0.3 per cent.

An incline tunnel was initially built for the construction of the twin track NATM tunnels constructed by Hochtief CZ, which are connected to the shaft. Later, this incline tunnel was used for muck removal by conveyor belt for approximately half of the running tunnel excavation.

Once the shaft was connected to the twin track tunnel, two short starting chambers, 10m long were built using NATM. The construction of the launch chambers was followed by the installation of a concrete cradle, in which the shield and cutter head was assembled. The TBM was then launched from a heavy steel thrust frame.

In April 2011 the first machine, Tonda, started boring towards Petřiny Station, making the first breakthrough to the partially excavated station (two side drifts were completed) in July, followed by Adela less than two months later. In the station

the concrete cradles served for the passage of the TBMs and at the end of station two short 10m launching chambers and in-built thrust frame were constructed, allowing the re-launch of both machines towards the Veleslavin Station. Right behind the station the machines had to pass under the sensitive structure of a residential complex, where the maximum permissible settlement was restricted to just 6mm. The continuous monitoring system was installed in the residential complex, mainly in garages, allowing real time settlement values to be monitored on the TBM and in the site offices. The machines operated in closed EPBM mode for 150m of the route and the settlement limits were complied with, resulting in a maximum settlement of 3.3mm.

The relatively long stretch slightly over 1km between the stations allowed some high advance rates. The best day saw 25 rings, some 37.5m of tunnelling and the best month saw 630m of tunnelling.

The next breakthrough was into the Veleslavin Station, or rather to the open cut box used for station excavation. In the open cut the machines moved on a reusable steel support structure, and in the station concrete cradles were used again.

Right: Vypich site layout showing shaft

With the same arrangement as in the first station the launching chambers were constructed and the machines sent on a very short 210m drive to the open cut box on the Site E2. Supported by piling, the box is 53m long and 32m wide, with a maximum depth of 26m. The machines arrived to the open cut box in February (Tonda) and March (Adela) 2012.

In the open cut box the movable steel support was used again and machines were dragged through the box and both re-started boring in March, Adela following Tonda after a three week interval. The supply of segments and muck transport by conveyor belts was still managed from the initial launch site at Vypich. This arrangement continued until Tonda broke through into the partially excavated



Above: The E2 site with conveyor belt-supporting structures under construction

Cerveny vrch Station on 18 April 2012. The tunnel boring in this part of the route was affected by an eight-storey-high building, as well as five 15-storey high-rise tower blocks—all of them above or close to the tunnel alignment. Moreover, this area was in the past used for mining iron ore. An additional geological investigation for verification of the old mining works did not find any of the old works in the tunnel alignment, nevertheless the machines worked in closed EPBM mode in this area. Monitoring of the buildings was again continuous, with real-time values transferred to the TBMs and required terminals. The

settlements in the closed EPBM mode were 60-70 per cent of those in the open mode.

Construction of Petřiny and Veleslavin could not be completed while TBM supplies were passing through. After the Tonda breakthrough to Cerveny vrch Station, the second machine was stopped 230m in front of the station, before it reached the delicate geology under the high-rise buildings. With both TBMs in stable ground the supply system and muck conveyors were stripped out and rerouted through the intermediate shaft at site E2.

Both machines re-started boring in June this year. Tonda launched after being



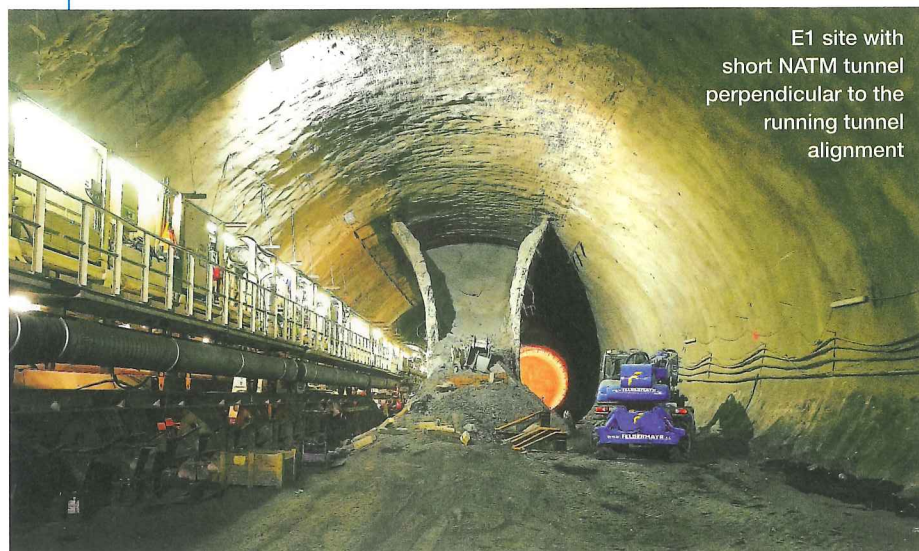
Above: Test ring assembly carried out during segment production at the precast factory

dragged through Cerveny vrch Station using the reusable steel support and a short starting tunnel with in-built steel thrust frame. The second machine followed the same procedure with a one month offset, after negotiating the short drive to Cerveny vrch Station.

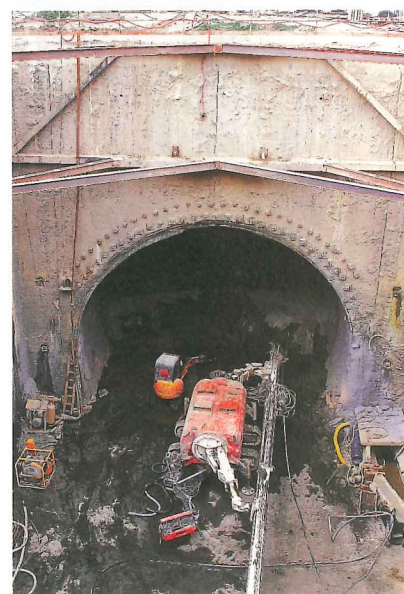
The final interruption of the TBMs journey towards Dejvicka Station will be at site E1, approximately 650m from the final breakthrough. The machines will pass through short 37.5m tunnels perpendicular to the alignment which have relatively large cross sections of 120sqm and a low overburden around 7m.

The tunnel was built by NATM with extensive jet-grouting to improve the ground. Both machines will have to pass through this tunnel, and later, after the machines are dismantled at the Dejvicka Station, the tunnel will allow removal of the shield and back-up.





E1 site with short NATM tunnel perpendicular to the running tunnel alignment



Above: Reusable steel support at Cerveny vrch Station

Logistics

H+E Logistik supplied the belt conveyor system consisting of 600mm-wide belts and including all supporting structures for 5.3km of tunnel: two vertical belt storage towers and main drive with installed power of two x 160kW.

The system was first installed on the Vypich site. Here an additional drive was added for an 800mm-wide, 300m-long belt that ran from the transfer station—situated in twin track tunnel—through the access tunnel and to the surface. Once the machines were behind the intermediate shaft at site E2, the whole system was transferred there. The belts at E2 are running directly to the surface, with a

relatively high gradient of 17 degrees.

A multi service vehicle (MSV) system was chosen for transporting segments and other materials. Altogether, on the site there are four MSV with 18t capacity supplied by Herrenknecht and manufactured by TechniMetal Systemes.

Experience from the site

Metrostav hired TBM consultant John Foster from the UK, who was involved in negotiations concerning the technical details and both factory and site acceptance procedures. Professor M. Thewes is also consulting on specific problems related to the TBM and segmental lining.

Since the TBMs delivery, Herrenknecht personnel have been permanently on site, as well as supporting from their factory in Schwanau, Germany. The cooperation of all involved was crucial in solving the usual teething problems, such as segment production, TBM assembly and start/restart situations. The assistance of specialised suppliers such as BASF, Mapei Condat and Minova was relied upon from the start.

The initial problems with two component grouting were overcome and the opening of the first cross passage in May 2012 confirmed the results of grout fill random testing—the annular gap is fully filled. Thanks to Metrostav's own improvements the cleaning procedures required were minimised.

In some parts of the tunnels segment cracking occurred, and extensive efforts were made to discover the reasons. The latest results show there were either several single sources, or a combination of factors leading to hairline cracks in the 250mm thick segments. One possibility is segments

cracking in the tail skin under pressure from the thrust rams, mainly due to tail skin drift, especially when TBMs were boring in the 660m curve and downhill with a four per cent gradient. The solution has been to improve the driving technique of the TBMs and to fine-tune the VMT system to include the tail skin position factor for the choice of segment type. The machines do not have active articulation of the rear shield.

The cutter head of Tonda was fitted with 20 no. 17-inch disc cutters at the start of boring, while Adela's cutter head was fitted with 17 rippers and four single-disc gauge cutters. In the first 500m of mixed face conditions, with clayey material and abrasive sandstone, the discs occasionally became stuck and damaged. After getting through such conditions, both cutter heads were fitted with disc cutters to bore through the shale.

The most complicated part of the construction process was, and still is, the frequent interruptions of TBM drives to pass the stations and open box. The site team made significant improvements by introducing steel structures for the TBM passage through partially built stations, which can be re-used for each particular TBM and also for differently-mined stations and open boxes.

With hindsight it could be stated that a different approach, allowing continuous boring with TBMs, would be more effective in terms of time and cost, and such a conclusion should be fully considered during preparation for the planned construction of Line D.

Status to the end of June 2012

By the end of June 2012 both TBMs had completed 4.6km of tunnels, which represents 55 per cent of the total running tunnels' length. The belt conveyor system from the E2 site shall be operational by the middle of June 2012 when Adela starts boring the remaining 230m to Cerveny vrch Station. One-month later Tonda will start boring the remaining 1.7km of tunnel. The machines are expected to complete their respective drives in November and December 2012. Dismantling will be done in the chamber prepared at the end of the existing Dejvicka Station, where the preparatory works have been underway since last year.

The opening date for the Metro Extension VA is scheduled for 2014, which marks the 40th anniversary of opening the first Metro Line in Prague. ■

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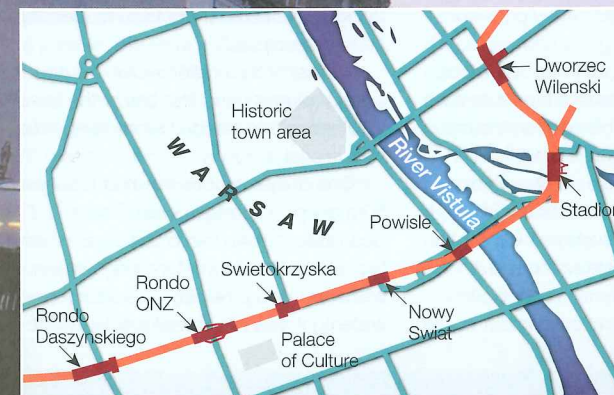


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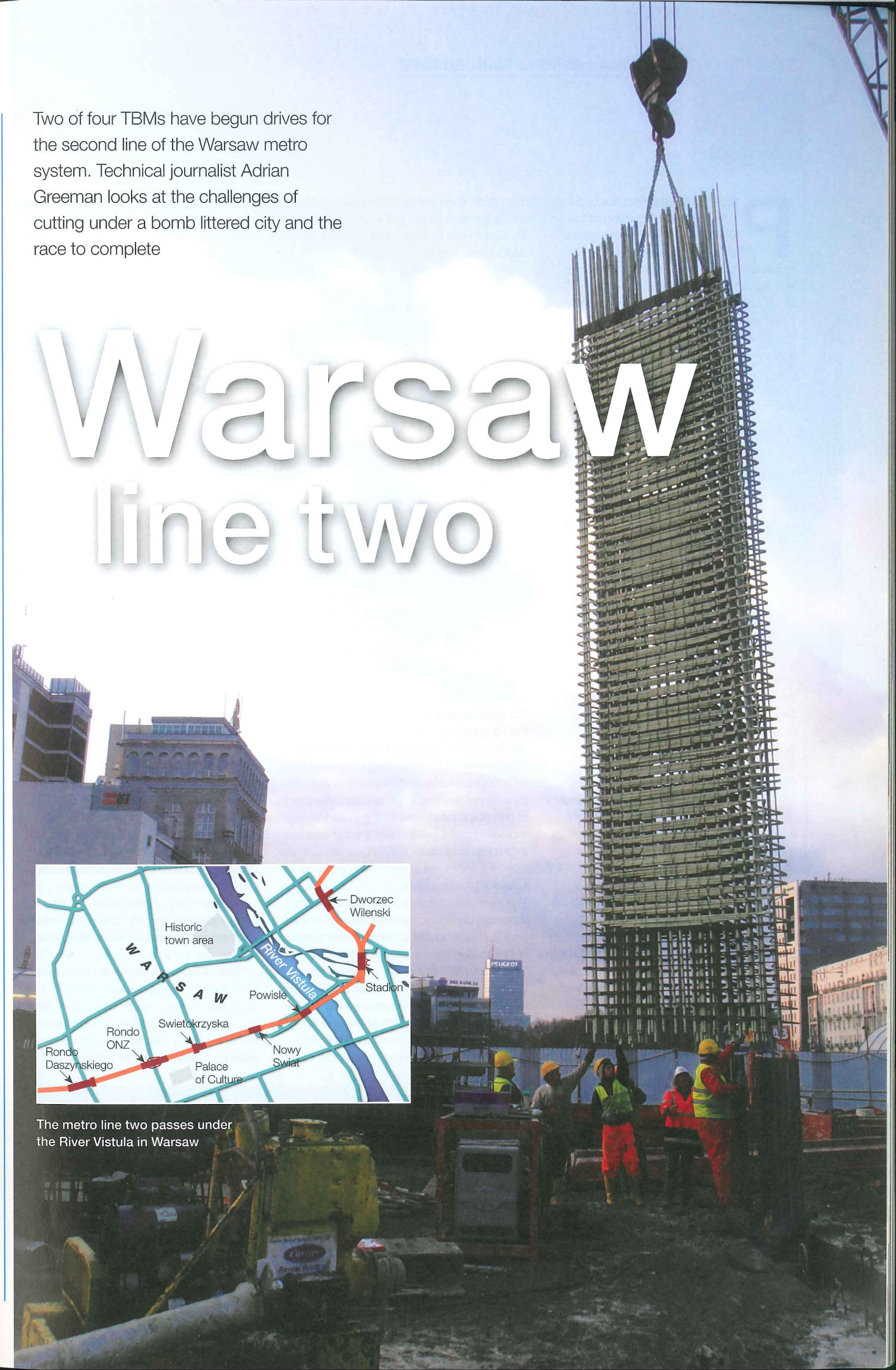
SCHAUENBURG MAB

Two of four TBMs have begun drives for the second line of the Warsaw metro system. Technical journalist Adrian Greeman looks at the challenges of cutting under a bomb littered city and the race to complete

Warsaw line two



The metro line two passes under the River Vistula in Warsaw





Polish commuters are doubtless hoping the construction of the second metro line in the capital Warsaw is completed

significantly faster than the first. Work on that lasted several decades, interrupted by the Second World War's Warsaw Uprising, Nazi blitzing and Soviet shelling, and then post-war financing shortfalls. Once fully underway in the 1980s it was held up and delayed by political upheavals too.

Technically, the new line should also be built much faster. With four modern TBMs to make the main drives rather than the basic cut and cover techniques used on the first project, the 7km long central underground tunnel excavation could be finished in 2013, with the line ready by 2014. Seven stations, and six other ventilation and power substation structures, will also be much quicker since they are using modern diaphragm wall boxed excavations.

Past and present

However, there may yet be some impact of the past on the project because the ground in Warsaw still contains numerous pieces of ordnance and unexploded bombs dating all the way back to the heavy fighting of 1939 and 1945. So far some 600 items have been encountered says Francesco Scaglione, contract manager and east Europe director for Italian contractor Astaldi, which has a lead role in the three firm consortium building the project. "Each requires stopping work and calling in the police and army bomb disposal squads," he says, "though that seems to happen quite quickly here."

The Italian contractor is part of AGP Metro Polska, a three way grouping along with Turkish firm Guermak Agir Sanayi Insaat and local firm Przedsiębiorstwo Budowy Drog I Mostow Minsk Mazowiecki which won the project in late 2009 for PLN 4.1bn (USD 1.2bn). The work is a four-year long package, a design/build contract for the new line's initial central section of some

7km and seven stations. Conceptual design and alignment for the bid was undertaken by a joint venture of BP Metroprojekt and AMC Choldzynski.

Another three stations will be added at either end once work is complete and design work for these was let in December last year.

"The complete second metro line will have nineteen stations eventually," says Mateusz Witczynski, a spokesman for the consortium, "extending as far as the Mor district on the western side and Brodno on the east." Total project cost is USD 1.9bn.

The current middle underground section runs through the centre of the city just south of its famous old town, the historic medieval city centre of Warsaw which was almost completely destroyed by deliberate demolition when Hitler's occupying troops retreated. Its streets, churches and state buildings were accurately rebuilt in subsequent decades. Further west the route passes another landmark structure, the giant Stalinesque 'wedding cake' cultural centre built as a post-war gift by the Soviet Union.

Eastwards the line includes a crossing underneath the river Vistula before curving northwards for the last two stations close to the city's former sports stadium and into the Praga district. This is an area of still surviving early twentieth century apartment blocks, once a poor working class area with river docks nearby and currently populated by a mix of artists and semi-bohemians. It is one of the prime areas of the city for redevelopment, particularly once the new metro link is in place.

Geology

The river crossing was regarded as one of the more challenging parts of the route says Scaglione, although in his opinion the rest of the line is probably the more difficult. "We drop a little deeper to go about 8m underneath the river bottom. At the 30m depth or so, we will be in clay which will be relatively comfortable next to the rest."

Warsaw's geology is a complex mixture of silts, fine and coarse sands, clays and organic loam like materials. Much of this is glacial and Ice Age deposits, the fine dust and debris brought by the cold winds blowing off the ice sheet and later alluvial deposits. There is also some limestone. "It's very confused," says Scaglione "and all jumbled."

"We also have to watch out for the danger of large boulders, as much as 10m across," says Scaglione.

Stations

Within this mixed soft ground there is a relatively high water table, particularly near to the river. In the original Line One this was dealt with by building large 'Berlin Wall' of kingpost and timber lagging, excavating and dewatering. For Line Two the stations have been and are being built as diaphragm wall excavations.

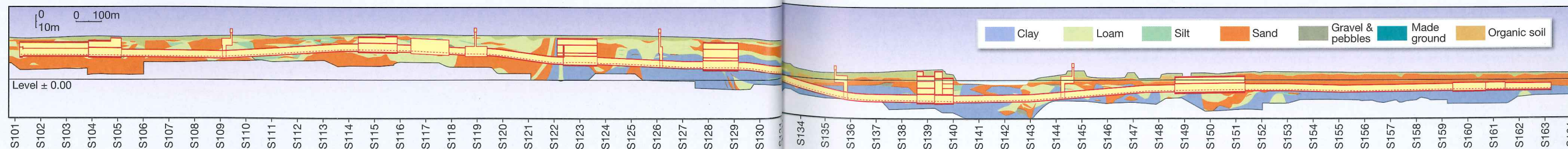
First work for the consortium however, alongside design effort, was to clear and divert services along the alignment at the station construction areas, which was time-consuming. "The extent of the services was incredible here," says Scaglione, "really something terrible." Some 77km of power lines were moved, 5km of gas piping, 5.5km of sewers and finally 3km of district heating lines.

Stations are primarily built as diaphragm wall boxes 150m long and 30m wide with some thicker sections of 1.5m. Excavation is top down, using concrete slab construction as strutting for the work as it drops down. Diaphragm walls are 1m thick and down to about 25 to 30m with a 2m thick base slab at about 20m to form the station space.

At most of the stations a jet grouted bottom plug is used first below the base slab to seal the station before the bottom slab is cast.

"One of the stations has much deeper, 50m deep, diaphragm walls," says Scaglione, "down into a clay layer which lies about 45m down. By using deeper walls and using the clay hat to form a watertight seal we can eliminate the jet

Below: Figure 1, geological profile of the metro's second line



Above: The machine being lowered down the shaft to bore the second metro line
Right: Herrenknecht manufactured the four EPBMs for the project. The machines have a diameter of 6.3m, giving a finished tunnel i.d. of 5.4m

grouting saving construction time."

At this station the TBM arrives quite early and there is no time to fully excavate to the necessary level for the machine to pass if the top down method is used, explains Scaglione. Excavation for this station and some parts of the Rondo Daszynskiego station used for the TBM launch pit, have been done in a conventional manner, therefore with construction to follow bottom up. "It means using struts but is unavoidable because of the sequencing of the TBM drives," he explains.

Bottom up will also be used for part of a station where the second drives begin their eastward course, since this too doubles up as a start shaft for the machines.

Excavation inside the diaphragm walls for these bottom up station sections is carried out by grab crane without dewatering so that the excavation is "like a giant swimming pool," says Scaglione. Dewatering would cause too many difficulties with the groundwater equilibrium. Once a base slab has been cast underwater the space can be pumped out before beginning construction work.

Most stations have a top entry level, a mezzanine and the platforms, though near the river crossing where the line drops deeper the correspondingly deeper stations will have four levels.

Difficulties in carrying out the excavations have included obtaining all the



necessary permissions for street excavation and diversions, which Scaglione declares to be a tangle of procedures and time consuming form filling.

The presence of unexploded bombs is also an obstacle as mentioned with several hundred items, large and small, discovered during works. "The largest was a 1.5t



Above: Segment stacking showing the five plus key arrangement

mortar shell from a Gustav mortar," explains Scaglione.

"But I must say that they are very quick in dealing with them here," he says, "[the process takes] just a few hours for something that might shutdown a site in Italy for several days."

Bombs have mainly been found several metres down. Scaglione says that over the decades the top two or three metres of ground have been fairly thoroughly examined. Bombs are not expected deeper down at tunnel level, which is at depths anywhere between 8m and 32m.

The excavation has also turned up other interesting finds he says including a tin box 'time capsule' from an old building foundation. Among other contents was a 1922 newspaper with, ironically for this particular consortium, details of an Italian-Turkish war of the time.

Tunnelling

A total 4.5km of tunnels will link the stations in six twin bore sections, each tunnel carrying a single direction of the line.

The tunnelling machines for this work meanwhile have been built and delivered by Germany's Herrenknecht. There are four in all with an outside diameter of 6.3m. Originally three were to be used but delays have occurred from street authorisations, and the bomb disposal. "And the services we have found include numerous unmarked and unrecorded lines," says Scaglione, "almost doubling what was anticipated."

The fourth EUR 60M (USD 72.63M)

machine will help claw back time on the schedule which was set an autumn 2013 completion date originally. Currently the line is likely to complete in early 2014.

Two machines began their parallel drives in May from a starting pit at Rondo Daszyńskiego while the others will begin in September from Powisle.

The EPBMs are relatively small, producing a tunnel with an internal diameter of 5.4m rather than a more standard 5.7m says Scaglione. The consortium suggested a larger size but Warsaw was keen to match the line with the existing Line One which uses the smaller size, and rolling stock to fit. A linking tunnel is to be made between the tunnels to allow sharing of rolling stock and maintenance facilities. The consortium's work includes three buildings for maintenance and train parking.

The lines cross at Swietokrzyska Station. "Passengers will be able to go between line platforms via a direct pedestrian corridor without leaving the ticket zone," says spokesman Witczynski. "It will also accommodate disabled people."

The Herrenknecht machines install a six segment (five plus key) universal ring to a design patented by Astaldi, with a truncated cone shape which will alter the tunnel direction according to its orientation and position of the key segment. Segments are 300mm thick and 1.5m long and are being made at a purpose built factory set up by Astaldi on the outskirts of Warsaw. It lies about 14km away delivering the 200kg segments by truck. They are loaded into

the construction shaft using portal cranes where they go to the face on tired multi-cars made by France's Metalliance.

"We are not using a rail system," explains Scaglione. Like many modern tunnels the muck out from the TBMs is by tunnel side conveyor, in this case supplied by Herrenknecht subsidiary H+E, and there is no point installing rail cars and locomotives. Spoil is taken from the entry shaft by truck out of the city.

The machines are relatively open faced for the soft ground but have cutter wheels too for getting through both the diaphragm walls on the stations but also in case of boulders in the ground. Glacial retreat left rocks which can be up to 17m across according to Witczynski.

Guidance for the machines is with the TunIS laser total station system from Herrenknecht subsidiary VMT.

Tunnelling challenges include the possibility of boulders in the ground but also another consequence of wartime damage. Two small blowouts have taken place in the first hundred metres or so, and the most likely cause is discontinuities in the ground left by backfilling of wartime craters, says Scaglione.

Scaglione explains that the foam ground conditioners being used on the project by Astaldi are all biodegradable.

Another challenge to come will be in a 300m length of the tunnel sections across the river where the line passes close to, and in some cases directly underneath some of the old buildings.

Mostly four to five storey apartments, these brick built structures are not necessarily in best condition. An umbrella of forward grouting using 24 drill holes in an arch shape forms consolidated ground along the TBM route is being used to try and prevent settlement. "It is like a 'pillow' underneath the buildings," says Scaglione, "and we hope it will be sufficient to prevent problems when we pass."

There will obviously be substantial monitoring he says. "All the sensitive zones are monitored, with some 5,000 instruments in total, including leveling pins, totalstations with miniprisms, piezometers, inclinometers, telltales and so on.

"There is a control centre to bring all this monitored data together and the results will be available continuously, 24 hours a day at a dedicated web page accessible by the contractor and the client. "The building owners will also be able to see relevant information summaries," he says.

That is all to come. For the moment the drives have just started, with 130m and 80m completed for first two in mid-July. ■



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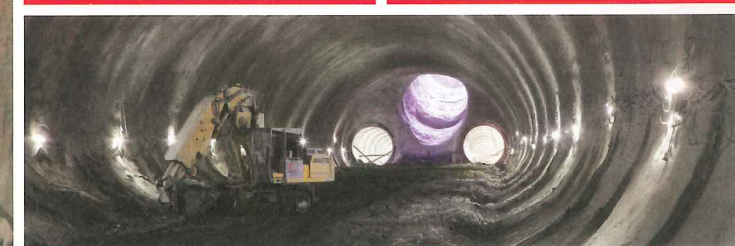
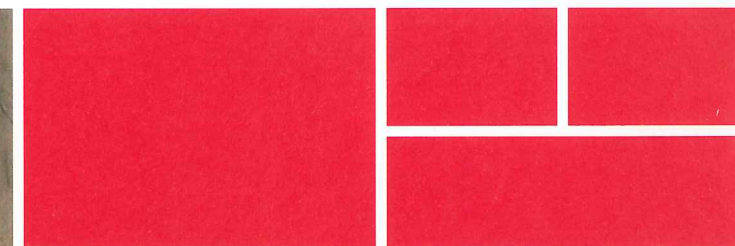
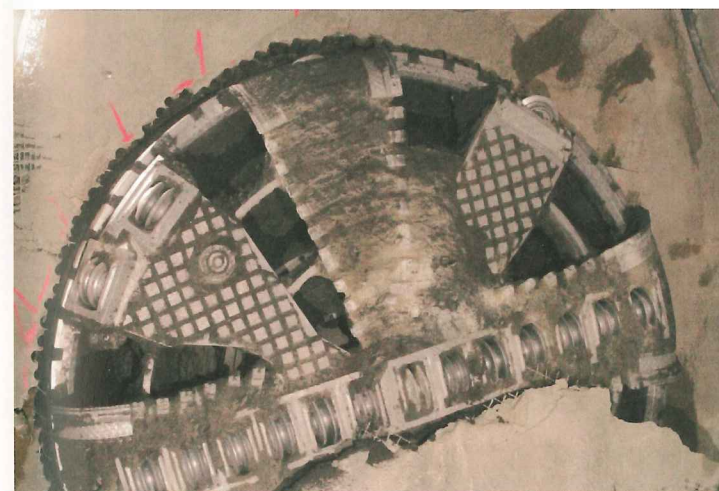
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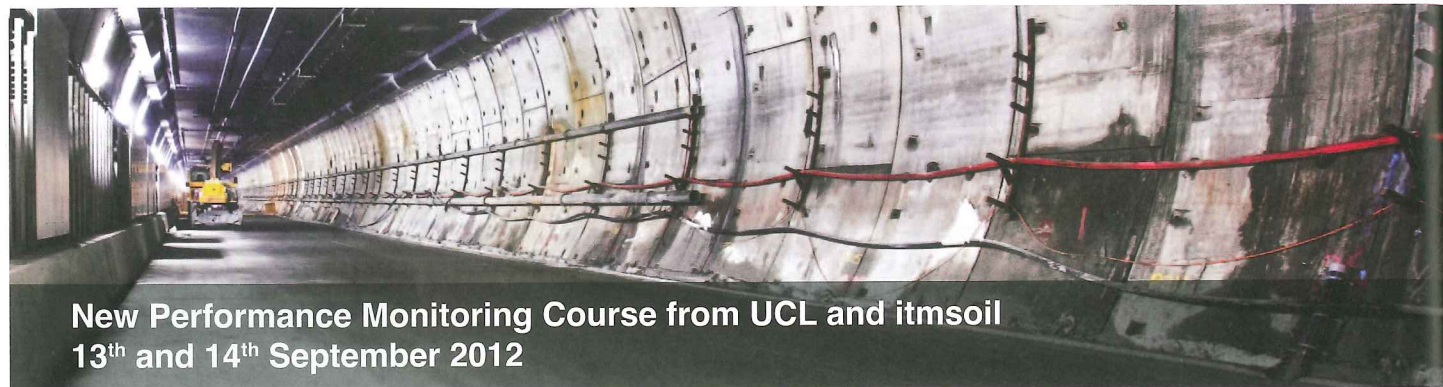


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Koralbm Tunnel main drive ready to roll

Site setup is strange on what was the largest construction contract in Austrian history. The Koralbm Tunnel (Kat) Two contract makes up the central 20km of the approximately 33km drive and will be linked to the portals by the completed Kat One section, and the Kat Three section, which will go to tender in early 2013.

There is the possibility of access via the Kat One drive, but due to Kat Two site preparations beginning before the full details for Kat One were finalised, a monumental shaft has been sunk to facilitate all necessary access for the second lot.

Alex Conacher speaks to Wolfgang Lehner, general manager of Strabag's tunnel department, as NATM tunnelling on the second Koralbm tunnel lot comes to an end and preparations begin for the main TBM drives

Access

The 60m-deep access shaft is a double cell excavation, with each cell measuring at 20m in diameter, giving a figure of eight shape when viewed from above. The top 20m are secant-piled with 1.2m diameter piles, then it is wire mesh and shotcrete reinforced. Excavation was carried out by a heavy excavator then mucked out by a

gantry crane (see image below).

"The shaft is so huge," says Wolfgang Lehner, general manager in Strabag's tunnelling department. "You can lift a boomer down it easily; and when the TBMs are running with 1,000t per hour vertical conveyor systems, the whole cross section will be free for lifting equipment.

"It was a major logistics challenge to

The dual shaft of two 20m diameter cells is 60m deep and constructed with 1.2m diameter secant piles. A gantry crane above is used for muck removal



Parties

- Contractor:** Strabag/Jaeger integrated JV
- Designer:** Geoconsult of Austria, Bernard of Austria, Lomarbi of Switzerland, Basler + Hofmann of Switzerland and IMM of Germany
- TBM Manufacturer:** Aker Wirth
- Segment design:** Zublin
- Segment moulds:** Herrenknecht Formwork

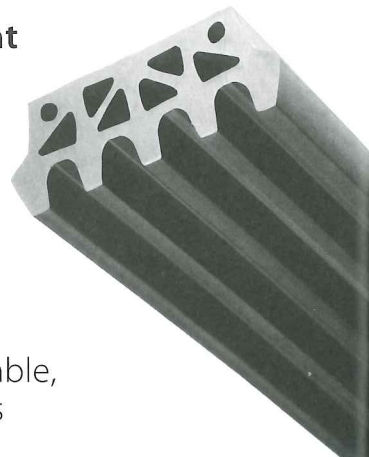
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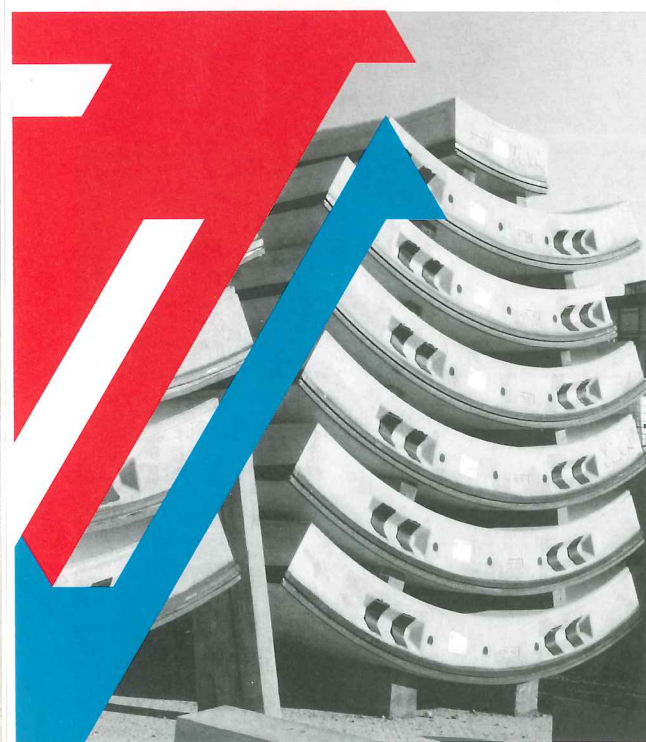
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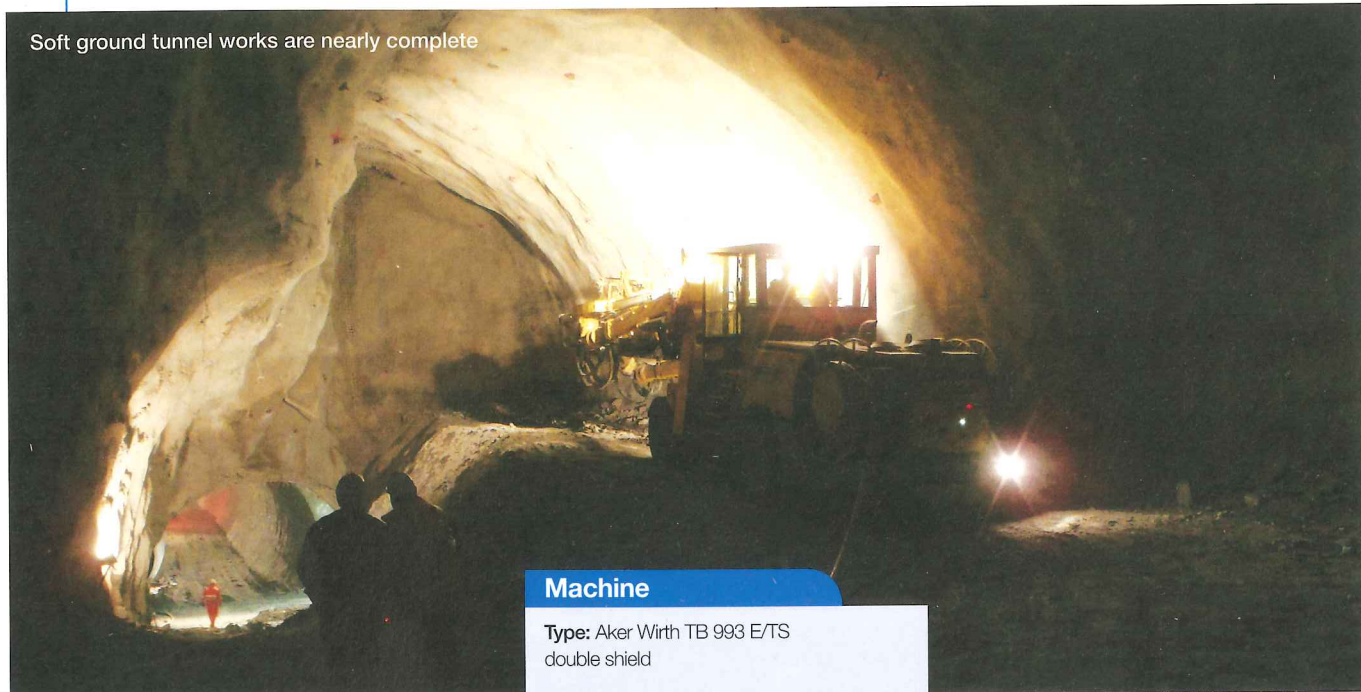
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plan, but once set up it is quite simple.”

Tunnels

The Kat Two lot covers works from the access shaft, some 3km from the eastern portal heading west towards Kat Three. Two single tubes (15.5km north and 17km south) will be excavated by two double shield TBMs.

Cross cuts will be constructed every 500m with an emergency station of 1km approximately halfway along the tunnel between the two tubes. This is a setup much in the style of the alpine base tunnels.

A total 4.5km of soft ground work across the Kat Two tubes will be excavated by NATM to launch the TBMs directly into the granite and gneiss.

Assembly caverns will be constructed by drill and blast with systematic rock bolting. Two Atlas Copco boom rigs, a Liebherr excavator and a BASF Meyco Robojet shotcreter will be used. Lehner adds that Liebherr made a dumper for mucking, which is quite unusual for the company.

Reinforcement in the NATM sections has been done with ribs and lattice girders at a 1.3 to 1.7m varied spacing. This is followed by layers of wire mesh with 200 to 250mm of sprayed concrete. Rockbolting was done with DSI self drilling rockbolts.

Lining will consist of precast segments for the main TBM section that will be cast on site to Zublin specifications using mucked material as the aggregate and rebar reinforcement. No poly fibres for fire protection are in use.

The bid

The Strabag/Jaeger JV was the only bidder that proposed a double shield machine, winning the contract in autumn 2010. Lehner said the contractor was surprised by this, but put the explanation down to differing experiences between the bids and methods. As well as the Strabag/Jaeger bid, client OBB received tenders from a Porr-led JV, Alpine and Marti, who all proposed single shields. The client did not permit drill and blast on the main section.

“Our experience on Niagara was probably important,” adds Lehner. “Leading to a low cost technique. We also already own a lot of the equipment and we changed the construction programme – applying the final lining after NATM excavation works to improve progress.”

Progress so far has been faster than expected due to good ground conditions.

No water has been met and waterproofing will not be needed until final lining installation in 2017.

By the end of August, soft ground tunnelling will be completed and the process to assemble the TBMs will begin. The first machine will launch in January 2013, and the second will lag this by some three months.

Ground challenges

The Kat One contract is entirely in soft ground. Kat Two has 1.2 to 1.4km of soft ground, and is then through rock. Kat Three runs through a major fault zone until the third kilometer, then it enters crystalline geology for the remainder.

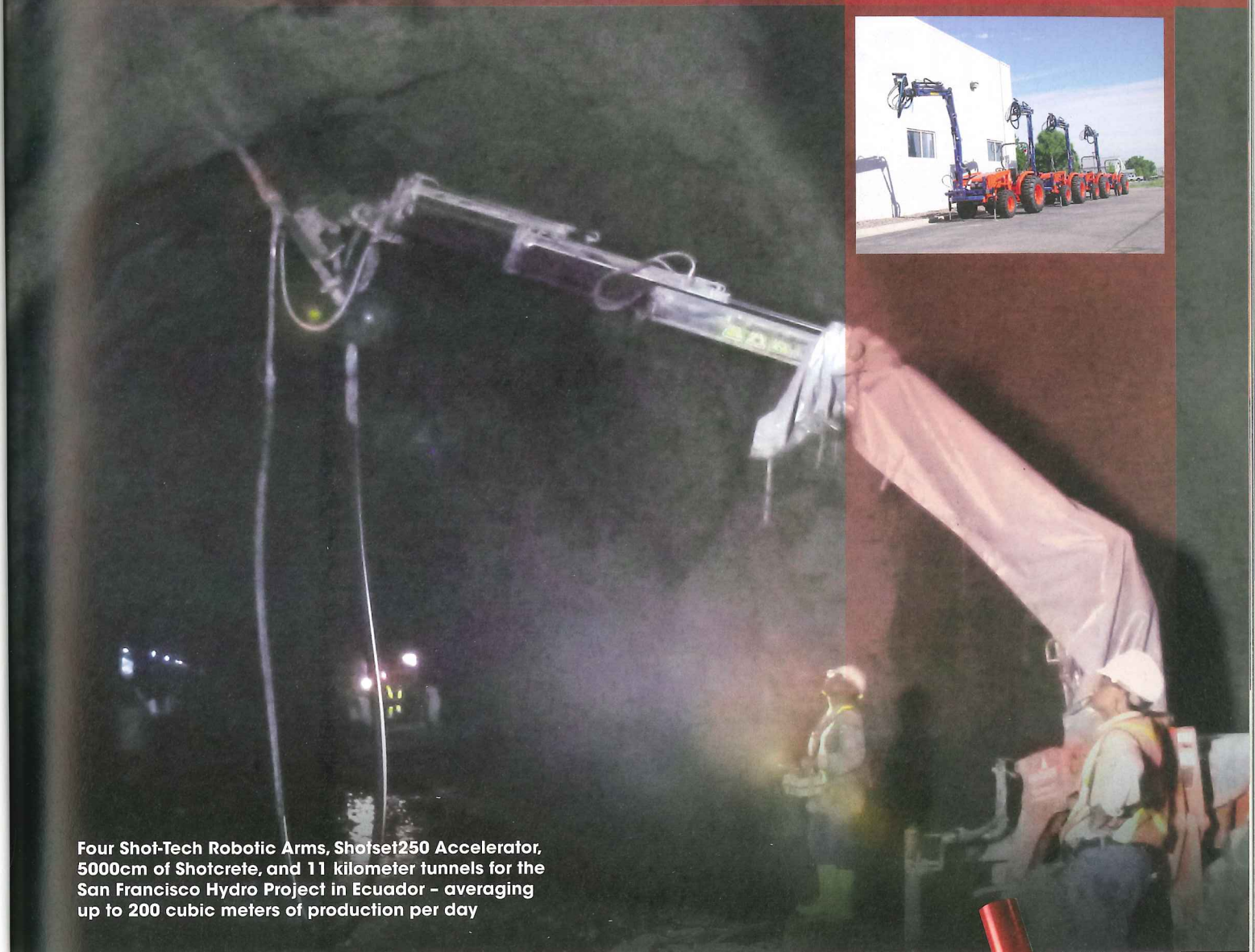
Lehner concludes, “I am obviously worried by the possibility of poor ground, the 1,200m overburden leads to a low density of investigation. The ground should be good, but there is a chance of rockfall, faults and squeezing ground.”

“In terms of the main challenge to come, it will be a test to reach our promised average progress rate of 23m per day. We run two shifts of nine hours, with a six hour shut down for maintenance, probe drilling and services.”

If the machines become stuck, a bypass tunnel will be constructed with drill and blast. Provisions have not yet been made for this, the plan is to set up the site properly when approaching a fault.

Regarding the Kat Three tender, he adds, “of course we are tendering, it’s one of the biggest coming projects in the region”. ■

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Turkish TBM boom



Left: The Kargi Kizilirmak HEPP, located in a remote area of Corum Province, will generate enough electricity annually to power 150,000 homes

The trend continued in the 1990s, though several programs began that increased contractor familiarity with TBMs, according to Ozdemir: "I got involved in Turkish tunnelling in the early 1990's, when I went to meet Professor Bilgin at Istanbul University. We planned and started giving short courses on mechanized tunnelling technology, in order to introduce Turkish contractors to the idea of TBM tunnelling. "In the mid-90's we were awarded a research contract from NATO to establish a rock cutting lab, similar to the facilities at the Colorado School of Mines in the US. Equipment included a linear cutting machine, a small boring machine, and test equipment for rock strength and abrasivity measurement. The university started doing

greatly following major reforms, and Turkey's credibility increased [with] European banks, thus opening up credit for the projects.

"Project handover lengths were shortened by the government at the same time that the build-operate-transfer model increased in popularity, demanding fast project completions. TBMs emerged as a solution for rapid tunnelling." From that point on, more and more TBMs were specified for challenging projects, including the first successful underpass of the Bosphorus dividing the Asian and European sides of Istanbul, completed in 2009 for a water tunnel project.

Sustainable hydropower

Most recently, the Turkish government put into place a nation-wide initiative for sustainable hydropower, particularly in the eastern part of the country. "Turkey does not have enough coal and oil reserves to sustain its annual growth rate, so the future [aim] will be to generate most electricity through hydropower projects," says Alpagut. "In the northern and southern regions of Turkey it is mountainous and there are many small rivers to be tapped as energy sources, but these are often in difficult and harsh environments."

Overcoming Challenges at Kargi

One such project will result in one of Turkey's largest hydroelectric stations, located in a remote area of Corum Province about three hours from Ankara. The Kargi Kizilirmak Hydroelectric Project will source water from the Kizilirmak River to generate clean electricity. Up to 470GWh will be generated annually—enough to power about 150,000 homes. The project, owned by Norwegian company Statkraft, is scheduled to go online by the end of 2013.

A power station and 11.8km long headrace tunnel through volcanic rock are being constructed by contractor Gulermak. A 10m diameter Robbins double shield TBM is currently more than 350m into the tunnel after experiencing incredibly challenging ground conditions. Mixed weak ophiolite with high clay content and water inflows are keeping progress measured. The geology is expected to continue for the first 3km of tunnel, which will be segment-lined. After excavating this formation geology is expected to change to more competent basalt and andesite for the remaining 8.8km. Ground support will change correspondingly, to ring beams, rock bolts, wire mesh, and a final lining of steel fiber shotcrete. "The types of ground support made the design of the TBM and

Above: A 10m diameter Robbins double shield TBM will line its headrace tunnel with segments for the first 3km, switching to ring beams, rock bolts, and wire mesh in more stable ground

was from 1987 to 1989, using a 5m diameter Robbins double shield TBM for the 2.4km long Dalyan-Moda wastewater tunnel in Istanbul.

Following that project, financial constraints and an unstable economy kept the tunnelling market small, while local contractors were more familiar with conventional tunnelling methods. A lack of available project funding led to several government initiatives to subsidise tunnel projects from an annual budget, which differed from year to year and increased the duration of tunnelling projects.

a lot of work with tunnel contractors and engineers."

In the early 2000's, work began on metro projects using EPBs in Ankara and Istanbul, and TBMs were specified in several hard rock hydroelectric tunnels. "From 2002 onward was a big turning point for the tunnelling industry," said Yunus Alpagut, owner of ATES Muhendislik Insaat San, which has been involved in the industry for more than 25 years. "A new government was elected that was eager to start large infrastructure projects. The financial capabilities of Turkish banks increased

With an economy growing at eight times the rate of many European nations and a young population expanding by 1.6 per cent per year, Turkey is a country in the process of massive civil infrastructure expansions. From road to rail, hydropower to wastewater, the nation is experiencing a rapid uptick in tunnelling projects.

Straddling the European and Asiatic landmasses, Turkey can be thought of as a geological patchwork, marked by older rocks mixed with younger igneous and volcanic rock types. More than 80 per cent of the country's land surface is rough and mountainous, making both agriculture and travel a challenge.

The numerous variables combine to make Turkey not only a hotbed for difficult tunnels, but also an emerging market for hybrid TBMs. "Turkey is seated on an active tectonic belt, and is especially complex," says Melih Algan, general

manager for Turkish consultancy Geoma. "In this type of geology typical problems are heterogeneity of ground and uncertainties due to limited site investigation possibilities.

"Practically, this requires flexible TBM systems to cope with differing ground conditions. TBMs with additional capabilities such as probing and grouting, over-excavation, bentonite injection systems, and controlled excavation (such as that possible with an EPBM) are preferable for owners and contractors."

Levent Ozdemir, mechanical tunnelling and mining consultant and retired Professor of Mining Engineering at the Colorado School of Mines, adds: "There is challenging geology and it is a high tectonic

area in Turkey. Contractors are looking for a machine that can go through any type of ground, just like everyone else. More EPBMs are running there now than in the past, and some slurry machines, and these conditions include variable ground."

While the current TBM market in Turkey is booming, that wasn't always the case. As early as the 1990s, there was only one instance of TBM tunnelling in a local industry more comfortable with NATM and drill and blast methods. Multiple factors, from government initiatives to fast-paced project schedules, have made tunnelling in Turkey what it is today.

The rise of TBM tunnelling
Turkey's first instance of TBM tunnelling



Above: The Robbins crew and contractor NTF stand in front of the 4.3m Robbins double shield for the Yamanli II HEPP, currently being assembled in Italy

back-up unique—there are many features that require adequate space, from shotcreting to rock drilling to segment lining,” says Jeff Gioitta, project manager for TBM supplier Robbins.

More than 150 people are employed at the site. “We have had some very impressive efforts by the Gulermak and Robbins teams,” says Glen Maynard, Robbins field service site manager. “After the TBM had bored 175m with a temporary conveyor system, tunnelling was interrupted to install the permanent tunnel conveyor system. Gulermak completed this installation in six days; on day seven the continuous conveyor system was operational, and normal boring operation was resumed.” Maynard explains that early signs on the project were promising with regards to TBM advance, with shifts topping 15m, and 20m daily advances becoming a regular occurrence.

Hydropower surge in Adana Province
Yet another example of the massive hydropower initiative can be seen in Adana Province, located in southern Turkey near the Syrian border. That region is home to the Yamanli I and II Hydroelectric Projects, as well as numerous other projects to harness power from the local rivers. Robbins project manager, Martino Scialpi, speaks of the remote jobsite that will host a 4.3m diameter double shield TBM: “It’s about 200km from the city of Adana, and only about 120km of that is paved road. It is located in a valley surrounded by high mountains, where there are numerous civil works projects underway—Yamanli II is the third hydroelectric project in this same

valley.” Because of the high elevation, crews are also racing to launch the machine before the end of September, as winter temperatures are known to drop to a chilly minus 20°C.

The hard rock machine for Yamanli II is set to excavate a 9.3km long headrace tunnel through limestone, with some karstic cavities and at least one fault zone expected. Crews for the contractor NTF Construction will conduct probing and pre-grouting in several target zones that are expected to contain more difficult ground. The completed headrace tunnel will source water from the Goksu River, with an annual generating capacity of 78MW—enough to power up to 78,000 homes.

High-speed rail and highway

Difficult access to jobsites in mountainous regions, including the remote Kargi and Yamanli sites, is a common problem. The dilemma is symptomatic throughout the country, spurring growth in the highway and railway sectors. New metro lines are being built in Istanbul, with a population of about 14 million, while long highway and rail tunnels are being planned to bisect the country. “Travel in the east-west direction of Turkey is easy, but to travel in the north-south direction there are high mountain ranges and long tunnels are needed. Mountain passes are also needed, and these are under study,” says Alpogut.

Dual mode TBM

A new machine design is being tailored for these often large diameter road and rail tunnels in variable ground. The dual mode TBM, for tunnels ranging from 12 to 15m in

diameter, is customised for the highly variable conditions seen in many of the country’s more mountainous areas, which can range from sandstone and mudstone to quartzite and schist. The hybrid TBM will feature a design optimised to switch seamlessly between pressurised and non-pressurised EPB mode, as well as hard rock mode. A retractable muck ring will allow the TBM belt conveyor to stay within the machine, so that in-tunnel conversions between a belt and a screw conveyor are not needed.

Soft ground and short sections of rock will be excavated using a specially designed screw conveyor, which can operate efficiently in both the pressurised and non-pressurised environments. The oversized screw can be rotated faster to handle short sections of hard rock while minimising any loss in efficiency. If a long section of hard rock is encountered, the belt conveyor will move forward and lock into place to allow non-pressurised rock boring through the section.

Projected growth

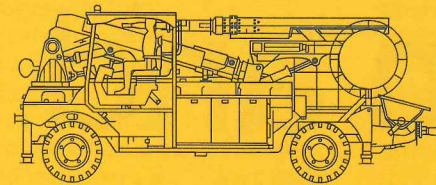
For the near term, projected growth in Turkey looks robust and there is general consensus that TBM and tunnel demand will continue to increase. “Istanbul is becoming the financial capital of the Middle East and Near Asia. Turkey is one of the most stable countries in the region, and many international companies are moving there. Turkish contractors are also doing more business in Middle Eastern countries such as Kuwait, Iraq, Saudi Arabia, UAE, Qatar, and Libya,” says Ozdemir.

With continued growth-focused initiatives, more challenging tunnel projects are being planned and are under study. One such project will involve twin 15km highway tunnels in the high mountains along the Black Sea from Rize to Erzurum, which Ozdemir notes will be very challenging. Others include a highway tunnel under the Bosphorus at water pressures up to 10 bars, which will need to be designed for stability in a seismic zone.

The speed with which Turkey has adopted TBMs and embraced underground structures makes it one of the most exciting emerging markets today. “The growth there is unbelievable. I go back there about three times a year and there are so many new TBM projects coming up,” said Ozdemir. “When I first was involved in the Istanbul metro construction, I was astonished to see that those tunnels were being built by NATM—a very difficult prospect in the city. Today, most metro tunnels are being built with TBMs.”

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Advances in SCL design and construction

This article presents the state of the art use of sprayed concrete with a variety of waterproofing solutions on major projects in the UK. It discusses the current design of permanent sprayed concrete and sprayed waterproof membranes and how SCL design may progress in the future. Report by Andrew Pickett and Simon Stephenson of Mott MacDonald

The traditional design approach, using lattice girders and steel mesh, sheet waterproofing membranes and cast in situ secondary linings has been significantly overhauled, providing many benefits to large projects. Typically current SCL design combines spray applied waterproofing membranes with sprayed concrete secondary linings. The design approach for all of the permanent sprayed linings, including the primary layer, maximises the use of robotics and mechanics that are capable of producing a high quality product in a safer, more robust and durable manner.

Setting a benchmark

Rather than taking a passive approach, and waiting for value creating design solutions from contractors at a later design stage, designers should be actively pursuing best practice and benchmarking it into the standard design. Discussions with product manufacturers and materials scientists have allowed understanding of the benefits and limitations of their design solutions and then apply them to SCL designs. Complex numerical modelling is carried out and calibrated to accurately predict the ground structure interaction thereby designing SCL tunnels with confidence. This is particularly important on high profile projects such as those located below the busy, high urban value streets of major cities.

The main advantages for these design developments can be seen through the

primary driver – the reduction of construction risks, and therefore improved safety. Comparative risk assessments have been undertaken to compare a traditional sheet membrane and cast in-situ secondary lining approach with the spray applied waterproofing membrane and sprayed secondary lining for a typical sized platform tunnel in the context of soft ground tunnelling in relatively impermeable ground. It was found that the sprayed system offers significant safety improvements, most notably in reducing the amount of manual handling, work at height and the combination of both. The methods proposed for the primary lining; using remote measuring technology, which allows construction of linings to profile without the need to install markers or lattice girders, and robotic spraying booms that can be controlled without exposing workers to risks of falling material, can also be applied to the waterproofing and secondary linings, allowing the benefits to be maximised throughout the whole construction cycle.

The advantage that follows on from this is a simplified, faster construction method, saving up to an estimated 25 per cent on programme for a typical underground station compared to traditional SCL tunnelling designs, with associated cost benefits. By using sprayed concrete, rather than cast in situ shutters and formwork, the installation of the secondary lining is both flexible and unrestricted, allowing the

contractor scope to make significant programme benefits and maximise the productivity of their staffing. Once trained appropriately the crews can be assigned to install the primary lining, the waterproofing or the secondary lining using overlapping skill sets and building on their experiences.

Where SCL design is now, and where it is heading

As discussed in the papers by (Thomas and Pickett, 2011, 2012) there are now several options for SCL tunnels open to tunnel engineers to suit different geological and hydrological conditions and/or the client's functional requirements.

The SCL options can be broadly categorised into three types:

- The traditional double shell lining (DSL)
- The contemporary composite shell lining (CSL)
- The single shell lining (SSL)

In most cases a waterproof membrane is employed to provide a watertight structure (in CSL solutions this is generally between the primary and secondary linings).

Double shell linings (DSL)

The DSL approach assumes a sacrificial primary lining which takes the temporary loads and a secondary lining to take the permanent loads. This has significant precedent, however because the primary is considered temporary the secondary is

designed to take all long term loading, the resulting lining system is a lot thicker than comparable CSL tunnels and therefore the DSL method is not considered further in this article.

Composite shell linings (CSL)

The CSL method is where the primary lining takes the temporary loads and a proportion of the permanent load through composite action with the secondary lining. Through recent projects such as the A3 Hindhead Improvement Scheme and Thames Water Hampton shaft, the use of sprayed waterproof membranes have given engineers an opportunity to explore the benefits of a composite shell lining, i.e. a sprayed permanent primary lining, sprayed waterproof membrane and a sprayed secondary lining, where the primary lining acts compositely and takes a proportion of the long term ground loads.

A key step that had facilitated this leap forward has been the omission of lattice girders and the use of laser profiling systems to control the shape of the tunnel during construction.

Lattice girders are usually not regarded as structural members but they have been seen as essential in controlling the shape of the tunnel. They are notoriously difficult to spray around and leaks, and therefore corrosion, often occur at the location of the lattice girder. Removing girders removes a corrosion problem, thereby giving an opportunity for a permanent sprayed primary lining, and also reduces the need for men to work at the face when the full support is not in place.

Composite linings are now being incorporated into major projects, typically into major projects, typically as shown in Figure 2 (right).

- The full 100 per cent ground and hydrostatic loads applied to the primary lining in the short term
- The option of load sharing for the ground loads in long term
- Full hydrostatic load applied to secondary lining in the long term
- No bond or shear capacity between linings is used in the structural design

This design methodology has resulted in some reductions to the thickness of the secondary lining when compared to conventional double shell linings but this is fundamentally limited by the assumption that the water pressure acts on the membrane. For a shallow tunnel in soft ground, the water load is similar or even exceeds the ground load. The percentage

of ground load on the secondary lining is usually determined from numerical models and it varies depending on the loading behaviour of the ground.

In materials such as clay, there is a distinct short and long-term behaviour, while in others there may be little or no change in the loads over the lifetime of the project from the loads generated during the construction period. In other words, without some consolidation or rheological behaviour in the ground, the secondary lining may not experience much of the ground load.

The first layer of sprayed concrete – the sealing layer of 75mm sprayed concrete – can be regarded as temporary and omitted from the design in the long-term. This is due to concerns over sulphate attack and poor quality when spraying on to the excavated surface.

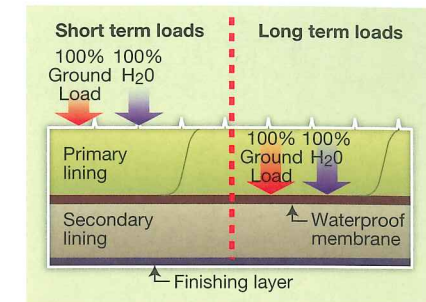
As T&T goes to press there is further study and testing being undertaken to demonstrate a fully composite lining as shown in Figure 3, i.e. shear and bond strength at the interface of the waterproof membrane. Once this is ascertained further reductions could be achieved for the thickness of the secondary lining:

- Composite action between linings by achieving shear capacity across membrane-concrete interfaces
- Load sharing for the ground load (GL) and water load (WL) in long term membrane-concrete interfaces
- Full hydrostatic load applied to secondary lining in the long term
- Bond strength on membrane interfaces to be 1MPa
- Shear strength on membrane interfaces to be 2MPa

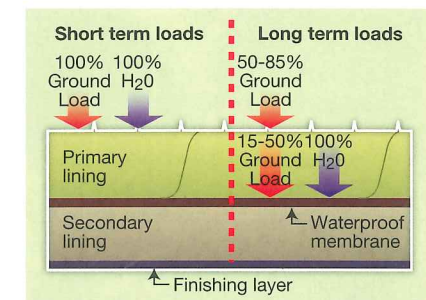
The advantage, as discussed above, is the reduction to secondary lining thickness without compromising the watertightness requirement. The main disadvantage is that there is currently no precedence for a fully composite lining with a spray applied membrane. However, single shell permanent sprayed concrete linings have been successfully used on a number of projects such as Heathrow Terminal Five (Hilar, Thomas and Falkner, 2005) and the design for Hindhead (Tucker, Stephenson, Chilton, 2010) considered both load cases – with and without full composite action.

Single shell linings (SSL)

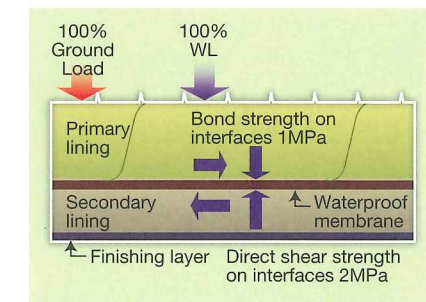
The SSL approach is where one lining takes the temporary and permanent loads, although this one lining may be built up in several passes. Single shell linings offer the



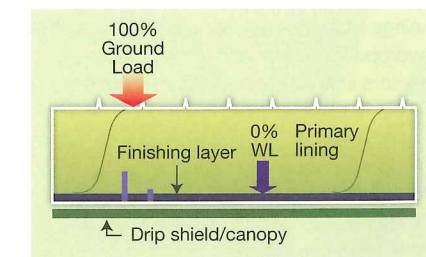
Above: Figure 1, Typical double shell



Above: Figure 2, Typical composite shell lining (partial composite with no shear or adhesive bond)

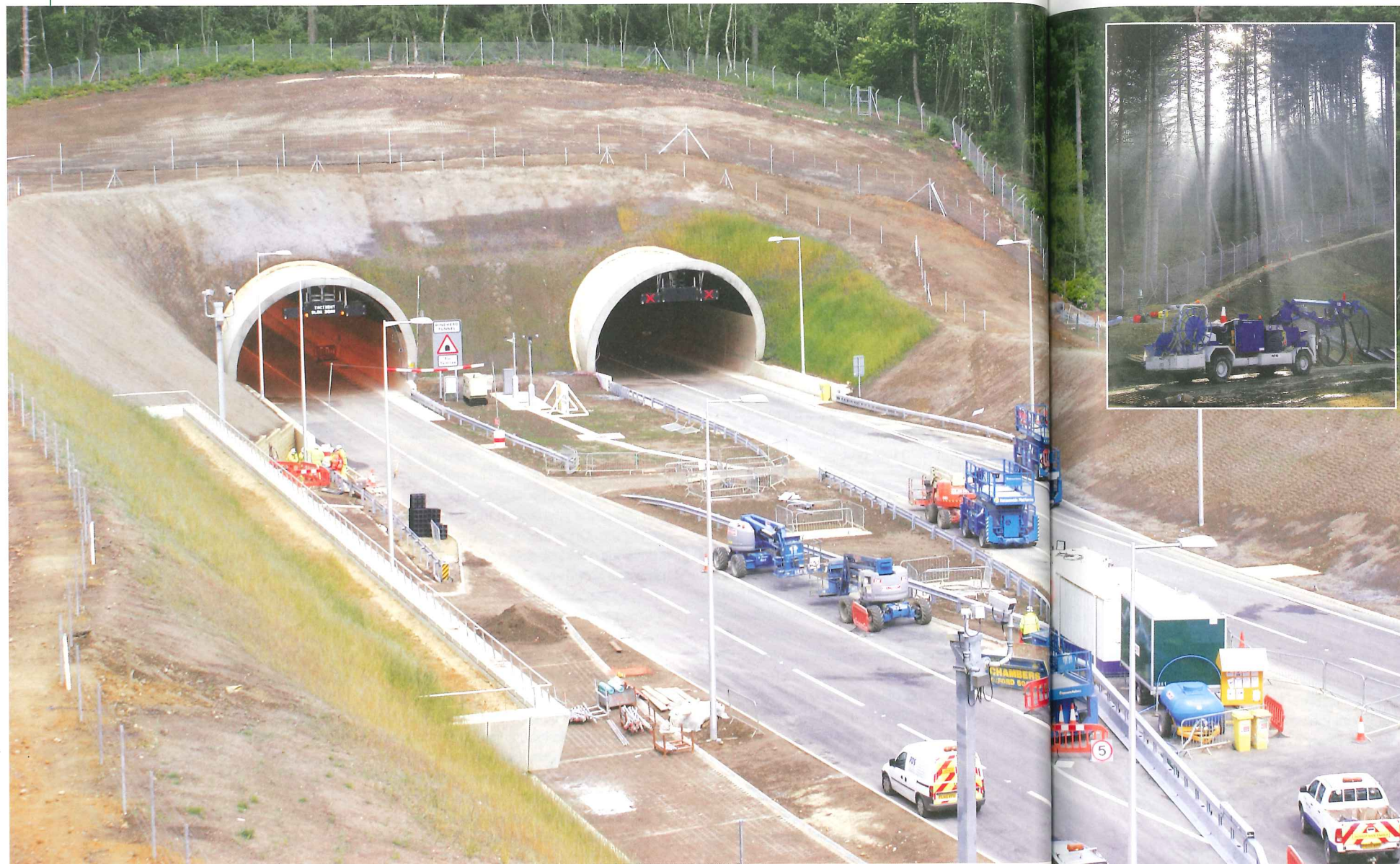


Above: Figure 3, Fully composite shell



Above: Figure 4, Typical single shell

most efficient lining design (in dry or largely dry ground) as they take both the temporary and long term loads and the construction is very fast compared to a double shell or composite lining where there are both primary and secondary lining stages to the construction. Single shell



Left: Entrance to the twin bore Hindhead tunnel, which was constructed using sequential excavation and SCL; Inset: The BASF Meyco shotcreting rig



savings of approximately 20 per cent were also achieved through geometric optimisation (the horseshoe shape) and lining thickness minimisation.

The lining system at Hindhead consisted of a 200mm fibre reinforced sprayed concrete permanent primary lining followed by a spray applied waterproofing membrane system. Secondary linings consisting of 150mm fibre reinforced sprayed concrete in the crown and 200 to 300mm cast in-situ concrete on the walls were then placed onto the waterproofing.

The primary lining was designed to be the permanent load bearing structure, providing all the required support throughout the design life of the tunnels. The secondary lining was designed to resist any water pressure developed onto the lining in the long term. It can also be considered sacrificial in the event of a fire, protecting the primary lining and ensuring its integrity will not be compromised by the heat generated.

Primary lining concrete mixes were developed by the contractor in order to meet the performance requirements specified by the designer. The requirements included short-term strength gain, long term strength, permeability, energy absorption and shrinkage as well as construction requirements for workability

Below: The spray arm advances ahead of the excavator to apply the SCL



linings have been widely used in the hydropower sector and in all tunnelling sectors in certain countries, most notably within Norway.

- No waterproofing membrane
- Ground loading all on primary
- Lining
- No hydrostatic load
- Watertight concrete design – but allows local seepage
- Optional drip trays provided outside architectural cladding

The main disadvantage is that clients will tend to opt for watertight tunnels thereby avoiding operation and maintenance issues and drainage systems. Unless the ground is dry or generally impermeable – such as

London Clay – it is hard to achieve watertight tunnels with single shell linings. That said, this can still remain as a design option for non-public tunnels where lower levels of watertightness are acceptable.

As with a fully composite type CSL, the ability to provide a single shell lining with a waterproof layer is being investigated by Mott MacDonald. This involves looking at the new technologies in sprayed waterproof membranes such as thin skin liners and whether they can carry out a dual role of initial support (sealing layer) and long term waterproofing. Other products are also being investigated such as the inclusion of polymer modifiers to give waterproofing capabilities. These may be incorporated into a sprayed concrete initial layer (approximately 25 to 50mm) and/or a single

pass SCL primary lining. The option of a hard sprayed waterproof membrane doubling as the final finish of the lining is also being reviewed.

Hindhead project case

A recent application of the CSL method of sprayed concrete tunnel construction was at the A3 Hindhead Improvement Scheme in Surrey, UK (Tucker, Stephenson and Chilton, 2010). This project involved construction of 6.7km of new dual carriageway, designed to alleviate the traffic congestion caused by traffic signals and a section of single carriageway on the A3 London to Portsmouth trunk road. Some 1.8km of the new dual carriageway was located within twin bore tunnels, constructed through a highly variable mix of

sandstone and sand, with more clayey sand towards the southern end. The tunnel alignment was selected to ensure that the water table along the route was kept below tunnel invert level, meaning that a drip-shield style waterproofing system was the appropriate solution.

The Highways Agency as the client employed main contractor Balfour Beatty under an early contractor involvement contract, with Mott MacDonald as contractor's designer. Having the contractor and design team on board at an early stage enabled many options for construction of the scheme to be explored. The SCL method was selected over a TBM mainly because of the high capital cost associated with a TBM. Excavated material

and retardation. Secondary lining concrete mixes had additional requirements for performance under fire conditions and the project team carried out large scale fire tests at the Building Research Establishment (BRE).

These enabled selection of the optimum mix of fibres and aggregates. The fire tests proved that the inclusion of monofilament fibres into the secondary linings significantly reduced concrete spalling under fire conditions.

The tunnel was excavated with large bucket excavators using a laser guidance system. The primary lining was then placed using remote controlled sprayed concrete robots, meaning workers did not have to perform tasks right at the face. Instead, they operated the machinery from several metres behind the face where the primary lining had gained sufficient strength to ensure their protection from potential face collapse or falling debris.

Mott MacDonald developed a 'menu' of pre-designed support solutions to ensure the ground support installed matched the geological conditions encountered at each face. The decisions about which support type should be used were reviewed at daily review meetings at which data from observations and measurements were examined. The data included ground settlements and tunnel convergence, geological face logs, records from probing ahead of the tunnel face, sprayed concrete strength gain records, and quality, environmental and tunnel inspections.



Above: Excavation work on the West Island Line in Hong Kong

The review resulted in the issue of a 'Required Excavation and Support Sheet' – in effect a permit to dig. The daily reviews allowed the contractor to achieve economies when practicable, saving time and cost without compromising safety.

The spray applied waterproofing membrane (Naylor, Stephenson, Salak, 2011) and secondary lining crown used the same skills and equipment as the primary lining, meaning that the same team could be used for each of these activities.

The secondary lining walls were cast using single-sided shutters to ensure access to the tunnels was not restricted. These measures allowed the team greater flexibility in the programming of work and

Acknowledgements

The authors would like to acknowledge the contributions of many colleagues at Mott MacDonald in the development of the design approaches. The authors would also like to thank BASF (especially Karl Gunnar Holter, Richard Foord, Kevin Stubberfield and Thomas Kothe) as well as Ross Dimmock and Bethan Haig at TAM International for their contributions in developing some of these concepts.

optimised the quality of the final product. Best practice specifications for product performance and installation were developed, resulting in a robust system that could be applied with confidence. The Hindhead improvement scheme opened on programme in summer 2011.

References

- [1] Thomas, A.H.; Pickett, A.P. The design of composite sprayed linings. Modern use of wet mix sprayed concrete for underground support, Tromso, Norway 2011.
- [2] Thomas, A.H.; Pickett, A.P. Composite Sprayed Linings, Alpbach, Spritzbeton-Tagung 2012
- [3] Darby, A.; Leggett, M. Use of shotcrete as the permanent lining of tunnels in soft ground. Mott MacDonald Milne Award submission (unpublished).
- [4] Hilar, M.; Thomas, A.; Falkner, L. The Latest Innovation in Sprayed Concrete Lining - the LaserShell Method. Tunnel – Magazine of the Czech Tunnelling Committee and the Slovak Tunnelling Committee ITA/AITES, Vol 4, pp. 11-19. 2005.
- [5] Tucker, N.J.; Stephenson, S.; Chilton, S. Sequential Excavation Method Tunnelling in Weak Sandstone using Innovative Methods. HKIE Civil Division Conference 2010.
- [6] Naylor, D.; Stephenson, S.; Salak, P. Practical experiences with Sprayed Waterproofing Membrane on three tunnelling projects in the UK. Underground Construction Conference 2011.

In the UK Mott MacDonald's recent projects include A3 Hindhead, the Heathrow Express Rail Link and Piccadilly Line extensions to Terminal Five and baggage tunnel at Heathrow. Internationally projects include new underground nuclear waste repository at Bataapati, Hungary, Beacon Hill station and the tunnel in Seattle in the US, West Island Line in Hong Kong and the Delhi Airport Link in India. ▀

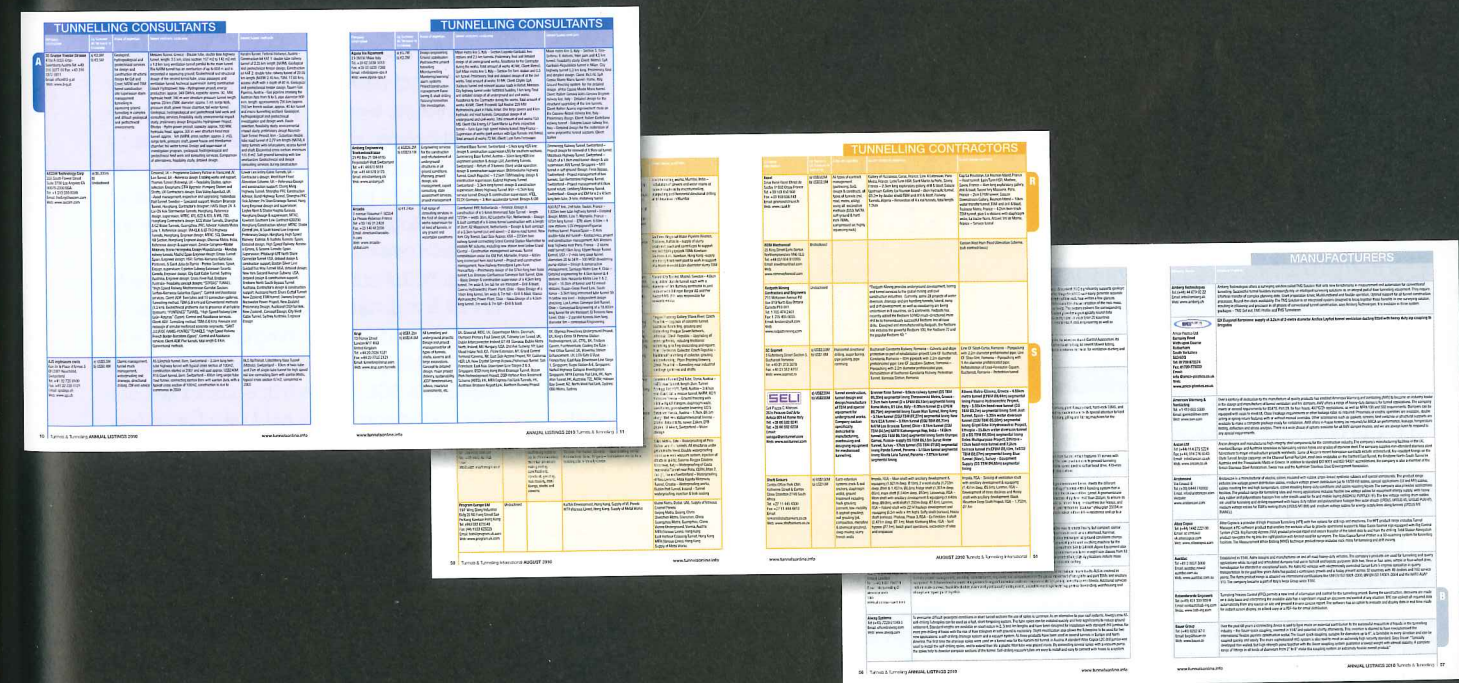
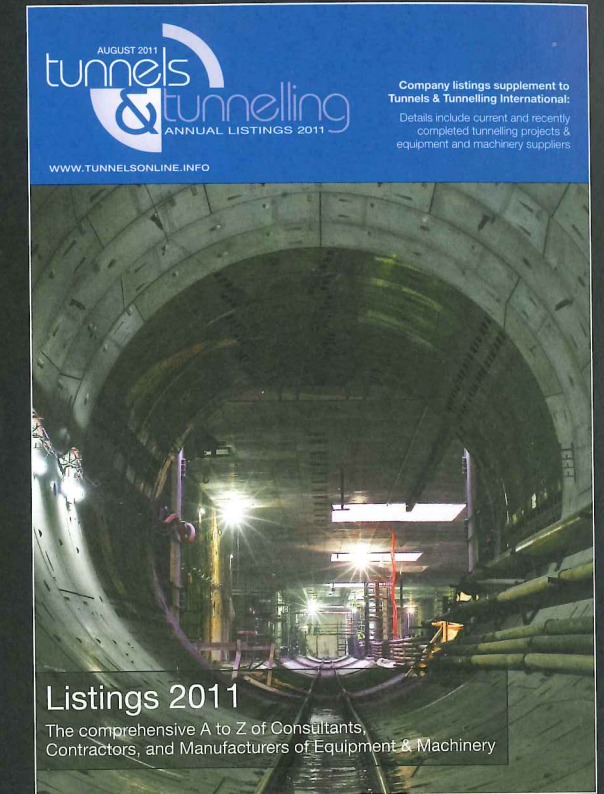


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Can someone please explain exactly what is SCL?

These days I despair for our tunnelling industry in the UK, which appears to have been hijacked by armchair experts, computer geeks and regulation fanatics, no more so than in sprayed concrete lined tunnels. Whilst I can see the need for some input from such specialists, when did we lose sight of the simplicity, elegance and practicality of the sprayed concrete method and replace it with the monster of their devising we now call SCL?

In any debate about the subject we must inevitably refer back to the New Austrian Tunnelling Method, which was not originally devised for soft ground but was adapted from its hard rock, high stress version by a collaboration between eminent Austrian and German engineers in the 1960s for use in constructing the Frankfurt Metro in a similar clay to that found in London. Perhaps it was a mistake to retain the NATM acronym for the soft ground version but the rather catchy name stuck and the method quickly caught on in Europe and then Worldwide for the very good reasons that it was simple, adaptive, cost effective and above all it worked.

Unfortunately, it met with massive resistance in the UK throughout the 1970s and 80s on several fronts, especially contractual, as it was difficult to incorporate the flexibility of the method within the rigid confines of the forms of contract in use at the time. Also, the traditionalist tunnellers vigorously expressed their scepticism by asserting that shotcrete was poor quality concrete that would not stick to clay or chalk, which was subsequently demonstrated to be erroneous on all counts. Perhaps the biggest anti-NATM cry was that it was neither new nor Austrian, which may well have been true, certainly German engineers had a big input and shotcrete had been used very successfully

A speedy and uncomplicated method has fallen prey to over-design and endless codes. David Hindle, partner of OTB Engineering speaks out on the present state of SCL design in the United Kingdom



Above: David Hindle

elsewhere, notably in Norway. However, I suspect that the main reason was that it had the word Austrian in it and not British. Incidentally, the acronym was originally adopted simply to distinguish it from the old Austrian tunnelling method and not for any overt nationalistic motives.

Eventually sanity prevailed and NATM began in the UK, not in civil engineering but in mining. However the inadequacy of traditional tunnelling methods to construct the massive underground complexes required for London's new transport infrastructure forced the UK tunnelling industry to adopt NATM and all went along swimmingly until the Heathrow debacle in 1994. What cannot be denied is that it was a monumental cock-up and the companies responsible were duly prosecuted. What then followed was a lengthy process of collective navel gazing from which emerged the SCL method.

What seems to have been forgotten was that all tunnelling methods can potentially fail given a particular circumstance or combination of circumstances such as poor design, inferior materials, substandard construction, poor supervision or unforeseen ground, but above all there is only one mechanism that causes a tunnel to collapse and that is gravity. Tunnelling in whatever context is in the end a contest against the force of gravity with gravity holding most of the aces.

Pick and mix

The mistake was that NATM was turned into cookbook of the engineering codes and standards beloved of the British engineer and has since evolved into a methodology that would make Delia Smith [a British cooking author] proud. The fundamental but true criticism of the NATM is that it was never clearly defined as to what it is and is attempting to achieve. Unfortunately the same can be equally applied to SCL. When this question is raised, one commonly held belief is that NATM is essentially an observational method whereas SCL is not; i.e. SCL is designed to cope with all the anticipated ground conditions and performance requirements. If this is so then what is the purpose of monitoring it? One would reasonably assume that it is to check whether the design is working correctly. If the monitoring shows that it is not, what then, change the design? If so then it is, by definition, an observational method. By way of confirmation an SCL design often incorporates some 'pick-and-mix toolbox' support supplements (rather like NATM).

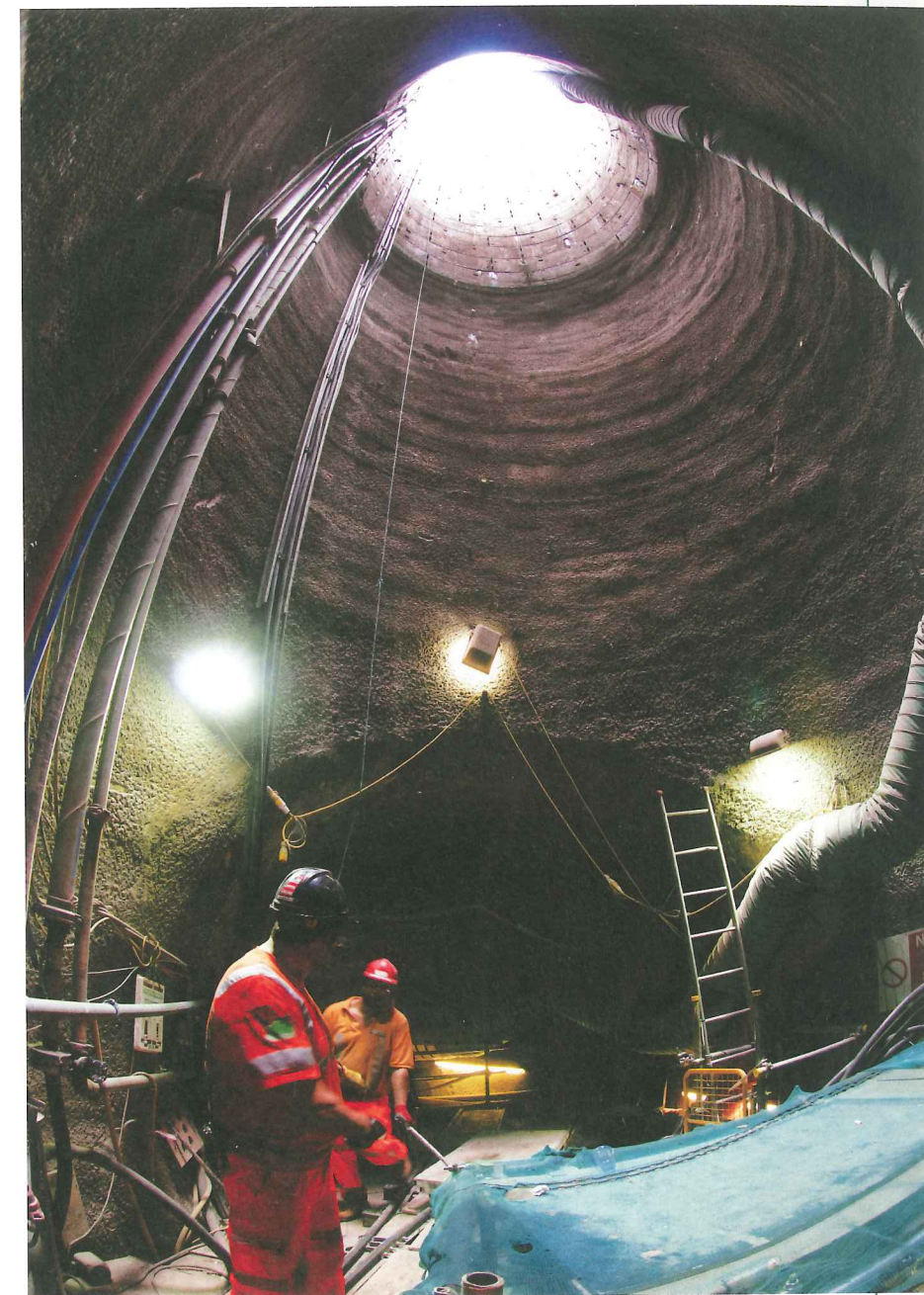
The SCL acronym itself is somewhat

misleading as it refers only to the finished product, when the fundamental key to its successful application is the sequential nature of the excavation and support and above all the most important design consideration is to close the invert as quickly as possible otherwise gravity (remember that irritating component) will have its evil way. So the best approach must surely be the simplest and quickest method in achieving ring closure and, to their credit, British contractors have looked to new technology to achieve this, such as semi-automated laser controlled excavation and robotic shotcreting. I would contend that this was the true and fundamental definition and aim of NATM that was developed using the best technology of the day to achieve rapid ring closure and should be the basis of SCL.

Spurious focus

Unfortunately, SCL development appears to have concentrated mainly on the sprayed concrete lining itself. For whatever reason there has been a fundamental shift towards very high strength mix designs and the exclusive use of steel and/or plastic fibres. On largely spurious health and safety grounds the use of lattice girders and steel mesh has been ditched and as a result we now have SCL linings double the thickness and twice the concrete strength, totally reliant on chemical additives and quality control of the mix and application for holding it up in the roof. Consequently, in a modern SCL tunnel you are at more risk of injury from falling shotcrete than collapsing ground (that damned gravity again) and I await with trepidation the first casualty in the UK – there has already been a fatality in the USA. Let me state my heretical view that fibres and high-strength shotcrete, whilst being very beneficial from a durability point of view, are no effective structural substitute for steel reinforcement both in the temporary and permanent condition and is no quicker to install, given the increased lining thickness and excavation volume required.

I recently had sight of an SCL design of 4m diameter, 12m deep shaft in London Clay. It has a lining thickness of up to 575mm applied in four specified layers. Not only that, on top of an under-reamed and domed, heavily reinforced base is placed a 0.5m thick reinforced concrete base slab below a further 1.5m thick mass concrete plug (you can't be too careful). From the shaft bottom a 3.5m wide cable tunnel is driven, which has a 425mm SCL lining applied again in four layers. The tunnel is (for no apparent reason) ovoid in



Above: SCL shaft construction on Tottenham Court Road station, London

profile requiring no less than seven setting out points and, just to be sure, has an 85mm internal profile tolerance, oh, and a further 75mm allowance for a drip-shield (you really can't be too careful). Amazingly this 'heroic' design has been constructed and I expect the contractor enjoyed himself hugely spraying up the world's most expensive textured rendering job.

Finally, let me air another heretical view that London Clay and the underlying Lambeth Group is arguably some of the best tunnelling ground in the World and,

rather than a soil, can often be classified as a weak rock. Perhaps it would do our armchair SCL designers some good to turn off the finite element program for an hour or two and venture underground to view it in its native habitat, then decide whether the computer output reflects reality or not. ■

Send your views to: editor@tunnelsandtunnelling.com or T&T Editor, John Carpenter House, 7 Carmelite Street, London, EC4Y 0BS, UK

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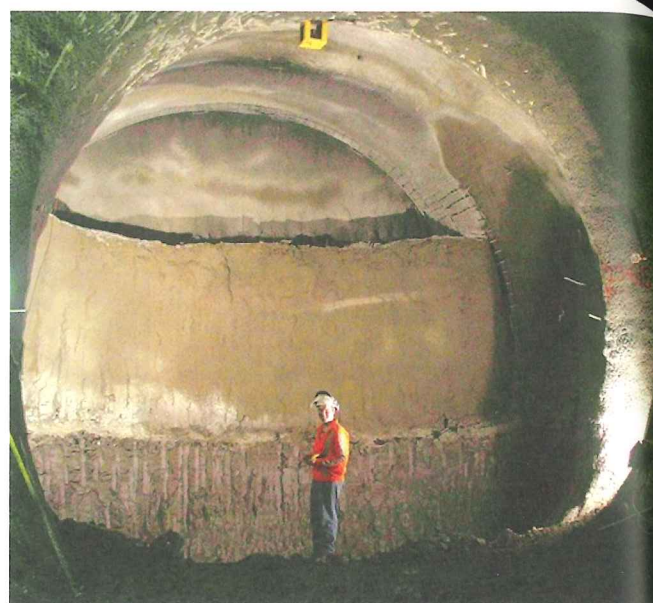


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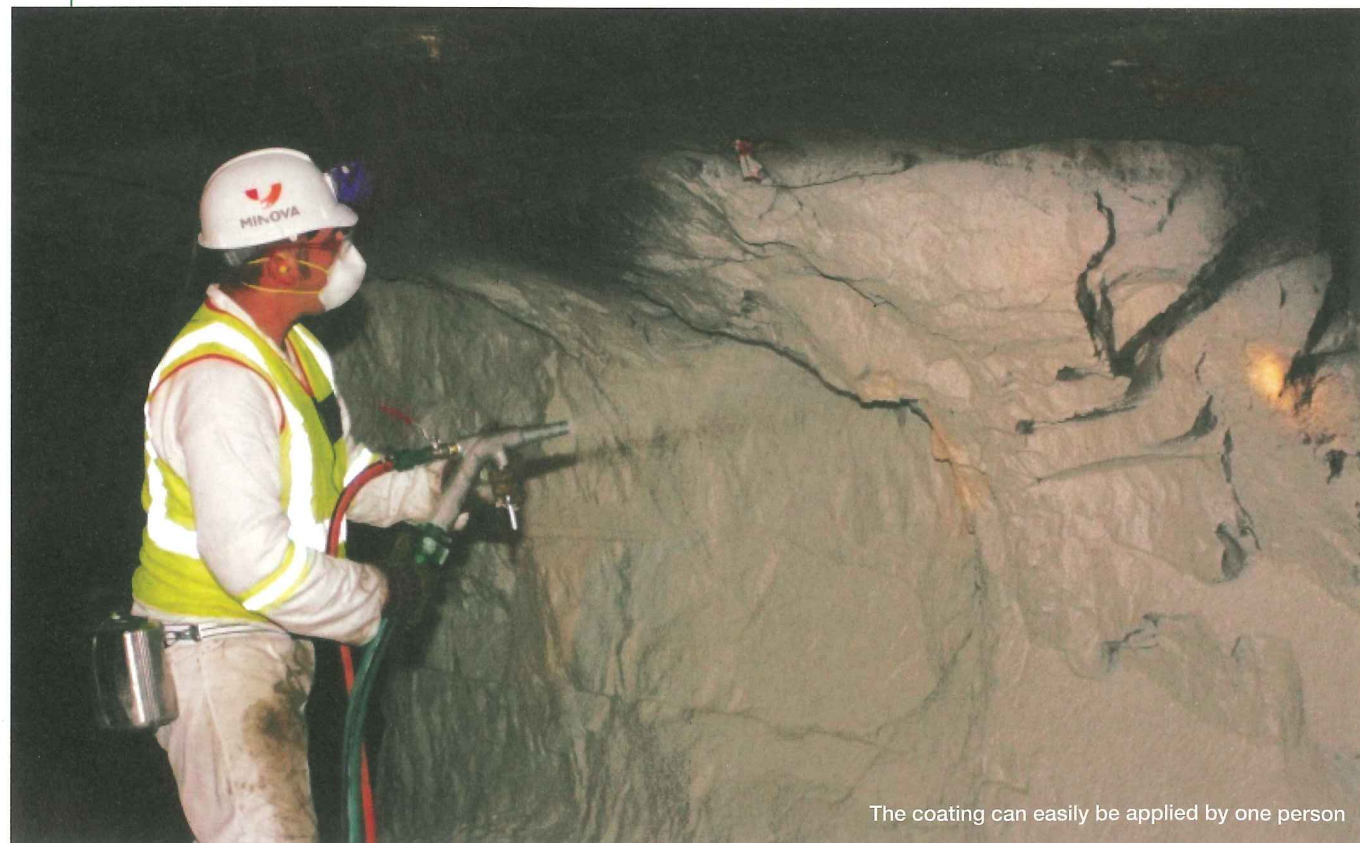
The thin sprayed line

P H Ferreira and Alfredo Piroddi of South African material and services supplier Minova RSA look at the use of thin sprayed liners and lessons that can be learned from experience in the mining industry

Pressure to provide a workplace free from injuries and fatalities has added to the worldwide market pressure to improve profits and margins in the mining industry. A rockfall study (Potvin et al 2001) conducted in 26 Australian underground metal mines has shown that over 90 per cent of rockfall injuries involved rocks smaller than 1t. Furthermore, studies have shown that most injuries in underground space have

occurred within a few meters of the active face. This suggests that the current approaches in controlling the small pieces of exposed rocks near the active face where workers are consistently exposed can be improved. The approaches used range from using no surface support to the installation of mesh (steel and fibre) and in poor ground conditions the installation of shotcrete. While applying the current methodology near the face would likely reduce the risks

of rockfall injuries, it could negatively impact the operations with regards to cost and mining cycle times. Thin sprayed liners (TSLs) can address the above mentioned problem. The installation of surface support using remote and rapid spraying techniques has the potential to minimise interference with the mining cycle and reduce costs. TSLs can be applied essentially on or at the face to keep the small key blocks in place and reduce the potential of gravity



The coating can easily be applied by one person

Table 1: Minova TSL characteristics summary at 25 degrees Celsius

Property	Tekflex	White	Grey	Fast	Fast 2C
Compressive (MPa)					
2 hours	A flexible product	0	0	9.9	8.9
24 hours		17.2	6.3	18.9	14.4
7 days		31.1	21.5	20.6	20.8
28 days	2.3	45.7	32.4	29.1	35.2
Tensile (MPa)					
2 hours	0	0	0	0.8	1.9
24 hours	0.21	1.4	1.6	1.5	2.4
7 days	2.1	2.1	2.6	2.0	2.7
28 days	5.15	3.1	3.1	3.9	4.8
Shear (MPa)					
24 hours	1.1	6.93	5.42	11.91	4.32
7 days	3.0	13.93	9.04	13.56	6.68
28 days	3.75	15.55	9.55	17.97	8.20
Adhesive (MPa)					
28 days	3.0	0.2	0.2	0.3	2.2
56 days	3.1	~ 0.2	~ 0.2	~ 0.3	4.9

induced fallouts of small pieces of rock.

The products discussed in this paper were all developed by Minova RSA, the intent being to compare the characteristics of each type of product against one another, rather than against those of competitive products. Minova RSA for the purpose of this investigation has chosen to evaluate their products against the following set of criteria:

- Characteristics of various TSLs
- Ease of application

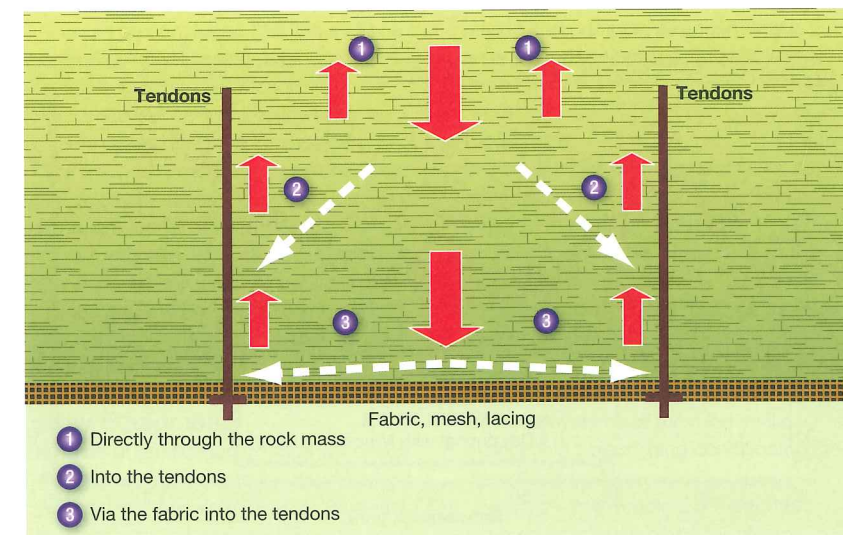
Product Quality Performance

- Spray ability and coverage
- Comparison to shotcrete
- Scale of interference and effect on the mining cycle

TSL characteristics

The Capcem KT range of TSLs provides a protective coating to rock, concrete or coal surfaces which are susceptible to deterioration on exposure to mine atmosphere, or as a TSL for support. These products are all compressed air propelled onto the rock surface.

Below: Figure 1, TSL block theory



Development of a full liquid TSL that does not require compressed air for propulsions onto the rock surface is in an advanced stage of development.

Critical requirements of TSLs have been identified as follows:

- Adequate pot life when mixing i.e. more than 30 minutes
- Factory pre-mixed products for consistent performance of product
- Fast development of strength for rapid performance after two hours of application i.e. compressive, tensile and shear strengths
- Excellent adhesion i.e. bonding to the substrate
- Visibility of the coating (white or light in colour)

The support performance of TSLs is largely determined by the substrates onto which it is attached to and can greatly assist in maintaining the initial integrity of the rock mass under general loading conditions.

To ensure effective surface support design, it is important to fully understand the required reinforcing capabilities of the skin support.

In friable ground conditions the first function of a TSL is to prevent the unravelling and loosening up of fragments, thus maintaining the rock mass integrity. If unravelling is not prevented, the support

resistance within the rock mass will gradually decrease and the demand on the surface support will inversely increase.

Being in intimate contact with the rock surface, the coating action of TSL bridges joints, effectively penetrates fractures and bonds the rock mass together, thus restricting inter block movement.

Figure 1 illustrates block theory with the interaction between various support components in a support system, represented as a reinforced beam loaded in an orthogonal direction.

Classification of TSL characteristics

Laboratory interpretation of TSL technical characteristics could be as detailed below but should be read in conjunction with the geotechnical requirements for the specific loading conditions that may be expected and may not all be equally important or entirely applicable.

In selecting the most suitable TSL, cognisance must be taken of the specific requirements and intended application of the TSL. For example, in a static environment the requirement may be for a TSL with a high uni-axial compressive strength where tensile strength capabilities are less critical.

Underground Application

Minova RSA TSLs are being extensively used at present in platinum and chrome mines with relatively limited application in other hard rock and diamond mines.

The Capcem KT range is used in most applications with specialised Tekflex applications in vertical settler dams and raise bore holes for sealing against water leakage and in excavations requiring flexibility. The application's success stems from the ease of mixing and spraying, and ultimately the cleaning of equipment after use. All this leads to quick and cost effective spraying cycles and will determine the success of the TSL application. Good surface preparation is also essential for a good bond.

Stress induced fracturing was observed in the rock mass surrounding the excavation and wedge type failure of rock occurred at the intersections of these and low angled joint sets, creating a very rough and uneven rock surface in the immediate hanging and sidewalls of the excavation. The condition of the rock mass around a tunnel is to a large degree controlled by the rock strength and the stresses it will be

Right: Figure 2, Graph showing force versus deformation during curing

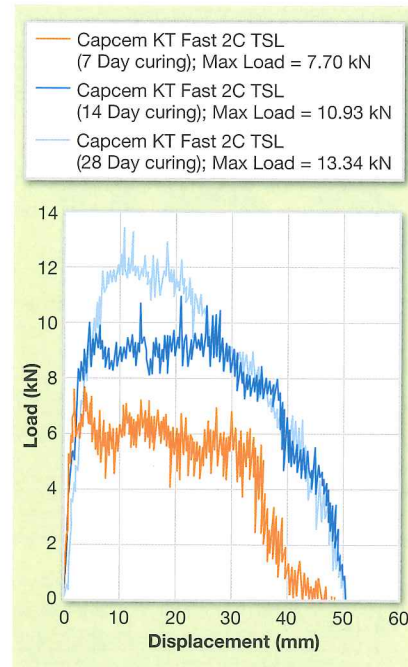
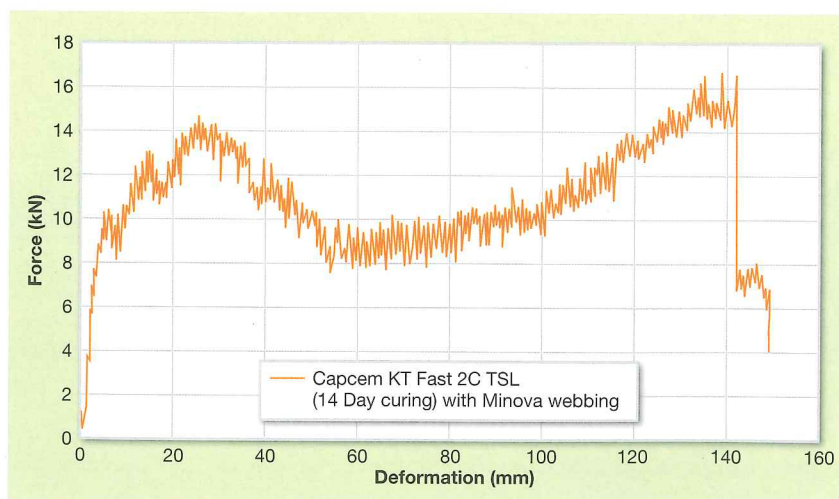
subjected to during its life cycle.

In high stress conditions, sound design and excavation techniques are required to reduce early fracturing damage and to prepare the rock walls for the installation of the support.

In these conditions, the installation of support at an early stage after exposure of the rock surface can significantly improve the prevailing ground conditions. It has become common practice in the deep level scenario to apply a thin layer of shotcrete as soon as possible after the blast to inhibit the adverse affect of stress fracturing and weathering, and to maintain safe working conditions till such time that secondary and more permanent support can be installed. However, it is often difficult to maintain the shotcrete within a reasonable distance from the advancing face, mainly due to logistical constraints and difficulty to fully integrate the shotcrete into the development cycle. TSLs have the potential to reduce accident levels and increase productivity, as the rapid spraying techniques involve minimised interference with the mining activity. In friable ground conditions the first function of a TSL is to inhibit the unraveling and loosening up of fragments, thus maintaining the rock mass integrity.

In relatively large excavations, tunnels and a mechanised production environment, the application of TSL is very well suited to a robotic arm spray system for fast and efficient applications.

If unraveling is not prevented, the support resistance within the rock mass will gradually decrease and the demand on the surface support will inversely increase. Being in intimate contact with the rock surface, the coating action of TSLs bridges joints, effectively penetrate fractures and bond the rock mass together, thus restricting inter block movement. More .



Above: Figure 3, load application on Capcem KT Fast 2C used with the Minova webbing

permanent structural support such as thick shotcrete can be applied on top of the TSLs with good bonding.

Product description

Capcem KT White and Grey have very similar properties and are supplied as a single component powder (pre-mixed in the factory) to which water is added. The White cures to a brilliant white, and the Grey cures to a light grey. Capcem KT Fast is a product developed by Minova RSA with the intention to provide early aerial support coverage to underground excavations offering strength after two hours. KT Fast

2C and Tekflex consist of two packed components: a pre-mixed powder and a liquid polymer forming a kit.

The range forms a semi rigid support membrane that assists the rock to retain its initial integrity by reducing the adverse effects of scaling, spalling and weathering.

It is supplied in 25kg bags which produce on average 15 litres of product when mixed with 5.4 litres of water or instead, of polymer.

It can theoretically cover 3.4m² if applied to a flat surface 5mm thick. However, due to the roughness factor of the underground rock, it is estimated that 2.5m² can be covered by one 25kg bag or kit.

Application Methodology

Typical mixing arrangement

The contents of a number of 25kg bags of White, Grey, or Fast is mixed together with clean water as per recipe, for approximately four minutes and then pumped (electric pump or compressed air driven pump), through a 25mm hose to the spray nozzle some 15m away from where it is sprayed onto the hanging and sidewalls either by hand held or robotic arm arrangement. The spray tempo is in the region of 500 to 800 litres per hour for effective application.

With continuous mixing of the TSL whilst spraying, a surface area of some 45m² can be covered in 30 minutes. Thus, a total cycle time of some 35 minutes measured from entrance into the tunnel to having moved out.

Minova RSA conducted numerous tests with TSLs to determine the relative performance of the products. Tests were done with TSLs only and also with a combination of TSLs with a relatively thin webbing being sprayed over. The results are illustrated below.

It could be concluded that TSLs offer a practical solution for limited ground support. If used in conjunction with appropriate webbing and followed in extreme cases by a layer of shotcrete, it offers a superb practical and mechanised solution to ground support in a sacrificial or permanent tunnel or excavation environment with increased safety as very few people are involved. All applications from the application of webbing to TSL to shotcrete can be done mechanised, remotely and fast.

Spray Equipment

The ease of application of TSLs will ensure minimal interference with the development cycle and improve safety and productivity. The equipment required for TSLs are small

Table 2: TSL technical characteristics

Uni-axial compressive strength (UCS)		
10MPa	20MPa	>30MPa
Weak TSL	Average TSL	Strong TSL
Tensile strength		
1Mpa	3MPa	5MPa
Weak TSL	Average TSL	Strong TSL
Material Shear strength		
5Mpa	10MPa	15MPa
Weak TSL	Average TSL	Strong TSL
Tensile adhesive strength		
1Mpa	2MPa	4MPa
Weak TSL	Average TSL	Strong TSL
Shear bond strength		
1Mpa	3MPa	5MPa
Weak TSL	Average TSL	Strong TSL

Table 3: Capcem KT Fast 2C

Age (Days)	Energy Absorption (J)
7	240
14	337
28	420
	+WEBBING
14	1680

when compared to conventional shotcrete equipment and can readily be moved between sites.

There are various types of TSL pumping and mixing equipment available, however the use of equipment with independent mixing and pumping arrangements is recommended to reduce the application cycle times.

Logistics

In the case of 25mm shotcrete, approximately 158 no. 25kg bags are required to cover an area of 45m², which equates to around 4t of material. In the case of 5mm TSLs such as Capcem KT, 23 no 25kg bags or 0.5t of material is required to cover 45m².

The use of TSLs can significantly reduce the demand on the already burdened logistical systems of the mine whilst maintaining safer mining conditions right at the advancing face.

A typical conventional development cycle might consist of the following:

- Cleaning operations
- Making safe
- Installation of temporary support (jacks and netting)
- Marking off support holes
- Drilling and installation of support
- Marking off of the round
- Drilling the round
- Charging up and blasting
- Removing temporary support
- Re-entry

Depending on the requirements, the application of surface support liners should ideally be integrated into the overall production cycle where it is most practical and causes the least interference with the development cycle. If it is required to apply the surface liner from the last line of permanent support up to the face, then ideally this activity should take place immediately after the installation of temporary support or even permanent support if a resin bolt installation is chosen. In a bad ground undercut development

Table 4: Product comparisons – Cost, application and time

Description	Shotcrete (± 25mm)	KT 2C (± 5mm) 3m ²	KT White (± 5mm) 3m ²	KT Grey (± 5mm) 3m ²	KT Fast (± 5mm) 3m ²
Approximate ex factory product cost per m ²	R 85	R 95	R 85	R 65	R 85
Approximate dedicated labour cost per m ²	R 125	R 55	R 55	R 55	R 55
*Approximate total cost per m ²	R 210	R 150	R 140	R 120	R 140
Rebound	Poor (lots of material)	Hardly any	Hardly any	Hardly any	Hardly any
Bags per m ²	3.5	0.33	0.33	0.33	0.33
Kg per m ²	88	8.35	8.35	8.35	8.35
Ease of Application	Cumbersome	Easy	Easy	Easy	Easy
**Time to cover 45m ² (conventional application)	150 Minutes	55 Minutes	55 Minutes	55 Minutes	55 Minutes
Equipment	Large	Small	Small	Small	Small
Inference with development cycle	High	Minimal	Minimal	Minimal	Minimal

*Product cost may vary slightly per m² from operation to operation due to surface areas. Labour cost for application could be very different from the numbers quoted above especially if the application crew is not part of the development crew.

**With continuous mixing arrangement of the TSL products, the application time can be limited to 30 minutes per application cycle followed by washing out the equipment before the next use. Minova RSA will ensure appropriate pump and mixing arrangements to allow for continuous mixing and spraying with the development cycle and equipment selection for development.

end the support regime might call for the following support:

- A bolting pattern
- Shotcrete at 25mm thickness
- Steel mesh and or lace installation
- Shotcrete at 50mm thickness

With the new generation support available the following could be proposed:

- GRP or synthetic netting installation with a netting installing unit mounted to the face of the jumbo
 - Some 5mm TSL on washed and made safe rock surface that is applied with a robotic arm applicator
 - A GRP and resin capsule bolting pattern with a mechanised bolter, this could be adequate to safely allow critical and in-line activities to continue at the face and then follow up with
 - Some 50mm Shotcrete approximately 20m behind the advancing face
- What the authors attempt to demonstrate is that a combination of TSLs, appropriate netting, GRP bolts and

shotcrete will offer the same support resistance but with less material, faster development cycles, safer development methods and support products that can be broken up and destroyed when an undercut level gets blasted away and product goes through the crushers.

Allowance must be made in the production cycle of at least half an hour for the application of the TSL assuming the product and equipment is on site.

This excludes the time taken to set up the equipment and the cleaning afterwards. Furthermore, it could be advantageous to spray a thin layer of TSL over the previously sprayed surface of the previous blast to increase the TSL thickness to say 8mm and produce a both good and consistent cover and protection.

Conclusion

Rock related accidents are the major cause of injuries and fatalities in underground and most of these accidents occur near the active faces where workers spend most of

their time. One of the major causes of instability is the lack of support and/or coverage between support units.

Support tendons alone do not provide sufficient rock reinforcement in friable ground conditions and hence the potential for the gravity induced fallout of small pieces of rock.

TSLs have the potential to benefit the works by offering improved productivity, profitability and safety.

From a manufacturing perspective it is very unlikely that all the characteristics that TSL could have can be included in one 'super' product. Proper selection and application of the correct TSL is very important to be able to improve ground conditions and reduce related injuries. ■

Acknowledgement

Article originally presented by the journal of the Southern African Institute of Mining and Metallurgy (SAIMM).



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Brenner behemoth

Professor Konrad Bergmeister, CEO of the Brenner Base Tunnel Company presented the project to the May BTS meeting

The Brenner Base Tunnel (BBT) is a railway line running through the Alps, connecting Austria and Italy. At 64km long it will be the longest underground railway connection in the world; a pioneering work of engineering.

In total the BBT system will include about 200km of tunnels, including the two main tubes, the exploratory tunnel, four lateral access tunnels and cross-passages. More than 20km have already been built. Completion is planned for 2025 and the start of operations for 2026.

The project company is BBT SE. The project will be financed by the European Union, Austria and Italy. The costs were estimated in January 2010 at EUR 11bn (USD 13.46bn). The European Union supports the expansion of this transnational railway and considers it a top priority. The BBT is at the heart of the Berlin-Palermo north-south corridor, also known as the TEN-1 axis.

The BBT will be primarily for freight transport, allowing a shift of traffic from road to rail. Passenger trains will also be able to travel through the tunnel. Due to an almost horizontal gradient, tunnel trains will no longer have to cope with steep up and down slopes.

History and situation

The BBT project was started in 1992 by Karl Van Matt, as part of the European north-south corridor, and it will eventually form a crucial link on the 2,200km rail link

Right: Figure 1, Brenner forms a vital part of a north-south European link



Speaker

Professor Konrad Bergmeister has been CEO of the BBT since 2006. He was previously the technical director and head engineer of the company managing the Brenner highway, and was responsible for the planning and construction of the new infrastructure, and for maintenance of the existing structures. For the past 15 years he has taught construction engineering at the University of Natural Resources and Applied Life Sciences in Vienna.

corridor between Berlin and Palermo. This first construction phase of the 64km long tunnel was started in 2007 and is planned for completion in 2026 at a total cost of EUR 8bn (USD 9.79bn).

The existing rail corridor running over the Alps is the most overloaded traffic corridor, and is continually under development. It has inclines of up to 28mm/m, resulting in slow movement of rail freight. The BBT will remove the steep inclines, and so dramatically increase the volume of freight along the European north-south corridor.

The northern portal of the BBT is at Innsbruck in Austria, the southern portal at Fortezza in the north part of Italy. The scale of the project creates numerous cross boarder challenges. The BBT connects two

different countries creating challenges by linking together two different cultures, different languages, five different voltages, different codes of practice and three different signalling systems. The BBT developed a cross border approach to overcome some of these challenges.

The corridor approach was needed in order to organise the rail logistics. The green corridor approach was published last year. This started in 2007 with the so called Brenner Based Platform. An action programme was signed on 18 May 2009 with all parties involved in the BBT (German, Austrian and Italian ministries, regions governments in Munich and Verona, and Rail Companies DB, OBB and RFI) with more than 80 points that had to

be respected by each party. Thus was formed the first European Company, which is chaired by two persons. Like a marriage, there are both good and hard times.

A planning approach was undertaken starting two years ago to include the environment issues, leading finally to the environmental impact approval applicable to both countries. This required dealing with two different approval parties and regulations. Some 3,800 plans and 44,000 pages were produced. This was delivered to the approval panels in both countries and was finally approved. This arduous task left Bergmeister with the impression that the purpose of these submissions was not serving the environment, but merely fulfilling regulations.

Up to code

It was necessary to produce a guide design, to create a basic platform to provide a very clear approach in how to deal with the project. This led to the first strategy and the guide design proved very useful for such an international project in order to bring together different codes. For example there are now Eurocodes, and Eurocode Two established a coefficient for

Below: At 64km, the Brenner base tunnel will be the world's longest transport tunnel





Above: Machine assembly on site
Right: The first Brenner base tunnel study was carried out in 1847, a second followed WW2 and a third in 1999

concrete of 1.5, but in Italy, where the financial situation is very bad, they decided to increase the coefficient to 1.6.

A working life for the structure of 200 years was established, which is quite unusual. Detailed interface plans are currently being developed including required tolerances.



With a total underground length of 64km it will be the longest transport tunnel in the world. There are two main tunnels of driven diameter of 9.5m, with a finished diameter of 8.1m. The distance between the tunnels is 70m, this was increased from the 40m spacing on the Gotthard tunnel. Also lessons were learnt from the Gotthard tunnel on classification of rock.

In addition there is the exploratory tunnel which is providing information on the rock. This exploratory tunnel will also be used for drainage of the whole tunnel system, with connections every 2km. It was also discovered that this exploratory tunnel could also be used to run power lines and as a service tunnel. In addition, every 330m there are connecting transfer tunnels, which house some technical equipment and will be used for emergency situations, allowing personnel to walk through to the safe tunnel and wait for the arrival of a train.

The first study of such a tunnel was carried out in 1847. The Austrian Governor asked an Italian engineer Giovanni Qualizza for a proposal to cross the Alps. He came up with a 32km tunnel, but at that time the technology was not available to carry out the work. After the Second World War a similar exercise was carried out, and finally in 1999 the so called preliminary project commenced. The exploratory tunnel was started in 2007 and is now in the third and final phase.

This project requires approval by both governments, and on an annual basis a cost analysis is carried out. This helps to monitor and control the project costs. For such a large project there is a long approval process, but it is hoped that the long planning stage will result in a shorter more efficient construction phase.

Questions from the floor

John Scholey of Jacobs asked for examples of what extending the design life to 200 years actually meant. He questioned whether designers actually understood what extending the design life meant.

Bergmeister explained that based on the Eurocodes which assume 100 years, the safety factors have been increased by approximately 10 per cent, the concrete cover has been increased, and some additional monitoring has been incorporated. Also, additional maintenance and inspection intervals are being incorporated.

David Hartwell of Halcrow asked about grouting and inflows and leakage, and said that obviously with the very deep tunnels, there could be problem areas. He asked for some idea of what extent of grouting could be expected. The fact that the project expects to reduce the permeability by two orders of magnitude, this could be a problem if hitting faults and joints, which are notoriously difficult to grout, once they have been struck.

Bergmeister said that on the basis of the exploratory drillings, it has been expected that on the south part there will be approximately 1,000 litres per second, and on the northern side, approximately 350 litres per second. The approval parties have been very careful to provide a lot of prescription which have to be respected in the face of excavation. We also will try further to gain more information from the exploratory tunnel, and understand the problem a little bit better, and more experiments will be carried out to assess the real inflows, and how this will affect the different types of mortars.

The intention is to assess if this type of procedure will be successful in the rock strata. Also, there are longitudinal pipes in order to be able to drain the water. Also, there are some big vessels to be able to cool the water down.

Hayden Davies asked for confirmation of the overall project costs, and asked if the price includes the ground treatment costs, as it seems remarkably good value. Konrad confirmed that the costs have been calculated as EUR 8.4bn (USD 10.3bn). Included in this amount were all the procedures and measures that must be taken into account to avoid certain situations. More than EUR 270m (USD 331.2M) have been foreseen for prevention measures.

More than 26km of drilling has been carried out, more than 0.4 times the length of the tunnel. A lot of time has been spent on this. In the surrounding zone of Innsbruck is the so-called quartz finitz which is a metamorphic rock with a uni-axial compression strength of approximately 30 to 40MPa. In the middle zone, is a schist, which is a fine grain rock created from the sea sediment approximately 120 to 140 million years ago.

On the south side of the tunnel is a very strong crystalline magnetic granite rock, with strengths of approximately 120 to 150MPa. This rock will be utilised for batching concrete.

Processes

The project will produce approximately 70Mm³ of excavated spoil, of which currently only 25 per cent is planned for reuse for concrete and engineering works, but with research studies and extra effort, it

is hoped to increase this amount to up to 40 per cent.

The cost analysis was carried out in a very careful way as it was recognised that engineers often underestimate costs. Along the Austrian side of the tunnel more than 7,000 contracts need to be signed with landowners, but in Italy, the situation is different resulting in signing only 30 contracts. This is big difference, and in Italy the excavated material can be sold, whereas in Austria the owners require payments for this.

External experts have been used to review the cost model, and it is felt that a very clear picture of costs and risks has now been developed. A very sophisticated risk analysis was carried out which has added seven per cent to the contract costs, but it is believed that only 1/2 of the risks have been analysed. Another eight per cent has been added to cover these unknown risks. An Austrian Railway Company

Mike McConnell retired from Balfour Beatty, also referred to costs, and asked for clarification on the 60 per cent civils costs and 14 per cent M&E costs. He felt that the M&E costs seemed rather lower than he would have anticipated.

Bergmeister said that the civils works included all tunnels, concrete within the tunnel, and the base plate for the rail equipment. The 14 per cent refers to the rail equipment, rails, technical electrical equipment, ventilation and cables.

Also there is another 11 per cent for management costs, acquisitions, and exploration. Some 15 per cent has been foreseen for the risk forecast. The rolling stock is not included.

Bergmeister also stated the BBT was also comparing costs with other big projects such as the Gotthard and Lotschberg tunnels, to see who could provide the most efficient tunnelling.

Maurice Jones from T&T referred to the care for the environment and the big communication programme, and also he recollected some green protesters in the early part of the project. He asked if the communication programme improved this situation and had there been some opinion polls for example.

Bergmeister stated that he has tried to improve the communication since he joined the project, and that public consultation was not normal for railway companies. More than 70 presentations per year were carried out speaking to the local population. He referred to one talk to the green party where all four of his car tyres were slashed. But however, the project tries constantly to keep the local people informed.

A question was asked over where legal and claims costs were taken from. **Bergmeister** said that included in each contract was a requirement that claims had to be discussed before going to court. An external judgement was included to assess claims, and project managers were being trained to have a weekly meeting to review these claims at a site level. In his opinion claims should not be solved by people who have never been on site.

BTS chairman **Damian McGirr** thanked Konrad for the presentation and particularly for travelling from Austria.

guideline has been used to work out the risks. The overall costs were calculated at EUR 8bn (USD 9.8bn) in January 2012. This overall cost is reviewed on an annual basis and is then communicated to the owner.

The project itself started approximately 10 years ago when the approval process required a groundwater survey be undertaken. Since 2001 more than 1,000 water sources have been and continue to be monitored, to enable a full analysis be carried out of the groundwater, in the zone where the tunnel will be driven. Macro modelling has been used to enable better understanding. More than 100km² has been modelled, to include every water source known at the moment, and studies were carried out both with and without the tunnel. By creating a grouted ring zone, the permeability of the rock can be reduced by approximately 100 (a factor of two), which will be implemented if a problem occurs during tunnelling.



Above: Construction work began in August 2007 for completion in 2025

Construction started in August 2007 and more than 20km of the exploratory tunnel and the external access tunnels have been driven. The intention is to complete all tunnels by 2025, and to start train operations on the 25 September 2025, exactly 200 years after Stephenson came up with the first train idea, which will be a very nice symbolic gesture.

In addition to almost 200km of tunnel to be excavated, also be constructed are the worksites, the connections from the Brenner Highway to the site areas, and the connections to the spoil disposal sites, some of which are in tunnels.

Driving forward

Some 75 per cent of the tunnel will be driven by mechanical methods and 25 per cent will be driven conventionally. On the northern side of the tunnel NATM is being used, which is also providing an opportunity to explore the rock condition, and use this information to provide knowledge and experience for driving the main tunnels.

Studies are in progress to find the right mix for the fibre reinforced sprayed concrete lining, to enable accurate analysis of the ongoing design and planning works.

Within the BBT company there are geologists, working seven days per week in the tunnels, mapping the geological conditions to assess the actual situation. The expected geology was quite different from that actually found.

On the southern part of the tunnel, a double shield machine has already excavated over 10km of tunnel, and there have been some failures of the tunnel lining. Therefore monitoring points have been installed to enable more accurate analysis of the loads being experienced, in order to calculate the stresses, and produce the right tunnel model. This will be helpful for the overall lifetime design of the tunnel, and will enable the theoretical model to be upgraded through experience.

There will be two main planning groups, one on the Austrian and one on the Italian side. It is expected that this will provide a common working approach to the planning of the works, and provide good practices and shared initiatives. There are planning applications required for the next phase of the works. In the southern section of the tunnel in Italy, over GBP 45M (USD 70.3M) will be spent on two planning applications, which is a very large amount, for the next 10 years of construction works.

Community and environment

It is very important on such a project to respect the environment, not only underground, but also on the surface. The surface worksites have been very carefully selected and at the moment more than 22 students are doing their PhDs and assisting on the project.

Open transparent communication with the public is also very important, and there are two communication centres, one in the south and one in the north.

The north centre at Innsbruck Railway Station has already had more than 20,000 visitors in the last year. The BBT is also engaging with the local community as a minimum on an annual basis, in order to provide the feeling that the project is growing with them.

Transparent communication during all phases of a big project is vital. Bergmeister claims the intention is to construct the longest planned underground structure in the world, through guideline design, a homogeneous planning basis, and through discussion and using experience from other projects, and simulation modelling, to bring the project to a successful completion. ▀

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At home in the Hoghouse

Bradley Gill, from Queens, New York, is a NYC Sandhog. The Sandhogs are miners that build New York's tunnels, whether train, water or the footings of bridges.

"Anything deeper than a grave in New York - we build it," he says.

In the past five years he's worked on the Seven Line Extension, Second Avenue Subway and, currently, the East Side Access project. Bradley describes his start in the tunnelling industry through the practice of 'Shaping', where workers show up at the job site to see if they are picked for the day. This could be because full-time workers called-in sick, are on vacation or if the bosses feel they need an extra hand.

"The first guys to get Shaped are guys who hold local 147 union books," he explains. "If they are all picked then guys who try to get enough shifts to get a union book will be picked. Everyone shapes at some point in their career; it's just the way it goes. When someone gets shaped it's their time to prove themselves and try their best to work as hard as they can to make a name for themselves. They do this hoping that they will continue getting Shaped."

"I remember my first time going into the hole. I was picked at 6:50 a.m. I was rushing and nervous to get changed as soon as possible. I rushed out of the Hoghouse and ran over to the top of the

Working on New York's mega-projects, one Sandhog, Bradley Gill, local 147, shares his experience 'Shaping' and helping to build the nation's largest subway tunnels. Nicole Robinson reports

shaft. Then a few other guys and myself entered the cage, which was connected to a crane, and were lifted way above Northern Boulevard. The sun was just beginning to rise and was blinding as we slowly began being lowered down into the shaft. This is where the trains would bring us deep into the tunnel.

"The job is not for the faint of heart or people who are scared of heights; I realised this that day. I stepped out of the cage and could see the trains in the distance but they had left already. So off I went on my 2.5-mile [4km] walk deep down under the East River. That was probably the longest, darkest walk of my life.

"The excitement was flowing through me so I jogged the whole way. By the time I got to the Robbins TBM I was physically exhausted from jogging to the work site and I hadn't even started work yet.

"They say your first day will make or break you in the tunnel and it definitely made me because the work was muscle-tearing tough. Now a few years later I have worked on three of the biggest tunnel jobs in America. There's not a day that goes by where I don't think of my first day Shaping. I see new guys doing it and I see the same look on their face as they enter the tunnel for their first time that I had."

The Sandhogs work around the clock in three shifts, and every day their duties are different. An average day in the tunnel could range from spraying shotcrete, to drilling holes to load dynamite for blasting, and actual blasting. Currently, on the East Side Access, they are building elevator and escalator shafts, which is increasingly problematic, Bradley says. "All the work we do is on a 30-degree angle. Another problem is we are a little under a 100ft [30.5m] from the Manhattan sidewalks or skyscrapers that hold up New York City's skyline. On the escalator shafts no dynamite can be used until we progress deeper down so there is no disturbance of the structures above us.

Left: Bradley Gill at work in the East Side Access tunnels

"Instead of dynamite, we use something called daymite. Daymite is a powder that when mixed with water, activates, expands and breaks the rock. It has been called 'liquid dynamite.'"

Working in New York means dealing with hard rock and, like all tunnelling jobs, carries the risk of injury or even death. "The hardest job by far was the Second Avenue Subway job. The rock was so bad we were mining through it and were worried about collapses. We would have to reinforce every 5 or 10ft [1.5 or 3m] because of voids."

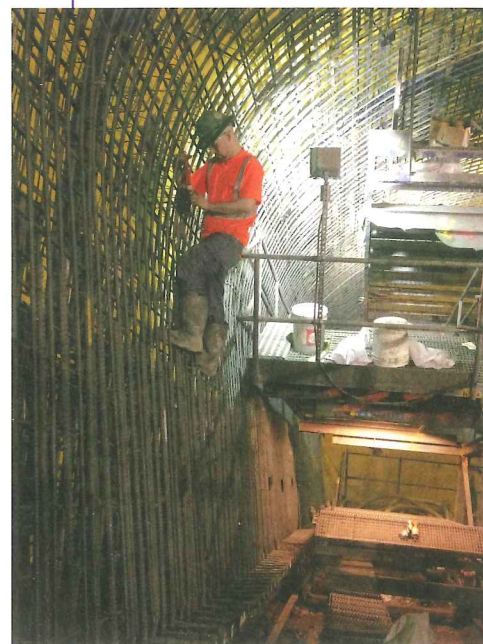
He adds: "For people just getting into the tunneling business I would tell them safety comes first and to watch out for your fellow coworkers. Sometimes one person might see something that others don't so it's very important to speak up.

"It's far from easy work so we all have to watch each other's backs 24/7. A man had died for every mile of tunnel built in New York City, so that right there shows you the risks we have to be aware of."

Among other traditions, the Sandhogs hold a huge picnic every July in Upstate New York. "It's a great feeling to take off the hard hats and the mud-soaked muck boots and just have everyone get together with their families. We eat good food, have a few drinks and just spend time outside of work. Sometimes when I see people at the picnic I don't recognise them without their hard hats. It's a nice to take a step back.

"Overall the best part about being a Sandhog is the fact we mine through rock and we go places that no one ever in the world has been to," he says. "We are truly the first. I can pick up a rock from the ground and just wonder how many millions of years it has been here.

"When people walk or take trains through these tunnels they will never think of the hard work, blood and sweat that the Sandhogs put into building these tunnels so their lives could be more convenient," Gill says. "It's not the men who work in offices or who work on Wall Street who build New York—it's the Sandhogs under the city, who most people don't even know about."



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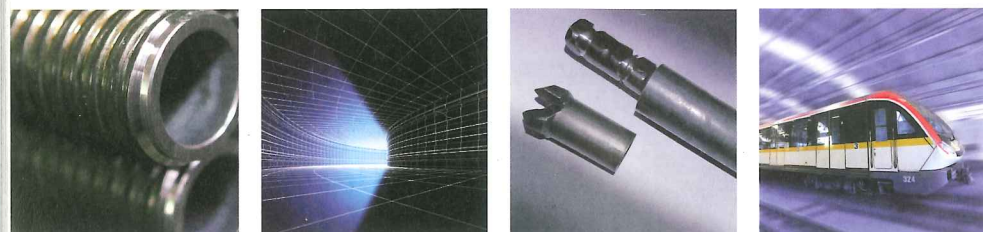


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2-4 OCTOBER 2012
No-dig Live 2012, Coventry, UK
The UK’s major biennial event showcasing trenchless technology and the best products and services applied to the new installation and refurbishment of underground utilities. 2012 marks the eleventh exhibition. More information at: www.nodiglive.co.uk or for visitor and exhibition enquiries, tel: Tel: +44 (0) 20 8876 1881.

8-10 OCTOBER 2012
Intermat Middle East, Abu Dhabi National Exhibition Centre
See www.intermat-middleeast.com or tel.: +33 1 76 77 12 08.

17-20 OCTOBER 2012
Montreal TAC 2012, Canada
‘Tunnels & Underground Spaces: Sustainability & Innovations: Sustainability & Innovations’, organised by the Tunnelling Association of Canada. For more info contact Wayne Gibson, conference manager, c/o Gibson Group Association Management, Richmond, BC, tel: +(604) 241-1297, email info@tac2012.ca or see www.tac2012.ca.

23-24 OCTOBER 2012
Trenchless Live 2012, Royal Melbourne Showgrounds, Australia
Live event for the Australasian trenchless industry, featuring hands-on and live exhibition and demonstrations of trenchless equipment. Info at: www.trenchless2012.com, or tel: +61 3 9248 5100.

7 - 9 NOVEMBER 2012
13th World Conference of ACUUS, Marina Bay Sands, Singapore
ACUUS presents ‘Underground Space Development – Opportunities and Challenges’ to focus on new opportunities in developing underground space as sustainable development. More info from E-Quezt Concierge, Singapore tel.: +(65) 6271 2453, email info@acuus2012.com or see <http://www.acuus2012.com>.

22 JANUARY 2013
11th George A Fox NY Construction Conference
Graduate Center, City University of New York, US. Organised by the SME - Society for Mining, Metallurgy & Exploration and sponsored by the Underground Construction Assoc of the SME. For more details tel.: +1 (303) 948-4200, fax: +1 (303) 979-3461, email meetings@smenet.org or see www.smenet.org

28-29 FEBRUARY 2013
Tunnel Design & Construction Asia 2013, Hong Kong
The conference is a platform for tunnelling industry stakeholders to discuss and share best practices in constructing efficient and sustainable tunnel infrastructure. More info at: <http://www.tunneldesignconstruction.com>, or email: enquiry@iqpc.com.sg

18-20 MARCH 2013
TU-Seoul 2013
Int'l Symp on Tunnelling & Underground Space Construction for Sustainable Development. Full papers due 31 July 2012. Visit: www.tunnel.or.kr

22-24 APRIL 2013
12th International Conference - Underground Construction Prague 2013, Czech Republic
The conference consists of technical exhibition, poster session and technical excursions. More info at: www.ita-aites.cz, or tel: +420 296 337 181.

27-29 MAY 2013
Suissetraffic, Geneva, Switzerland
Switzerland will host the 60th International Association of Public Transport world congress in Geneva. The trade fair brings together the railway, aerial cableway and tunnel construction sectors under one roof. More info at: www.suissetraffic-expo.ch, further info at: www.uitpgeneva2013.org, or tel: +41 31 340 11 11.

31 MAY - 7 JUNE 2013
WTC 2013, Geneva, Switzerland
World Tunnel Congress at International Conference Centre. Organised by Swiss Tunnelling Society. For more information tel.: +41 (0)81 725 31 32, email sia-fgu@swisstunnel.ch or see www.wtc2013.ch.

16-19 JUNE 2013
Strait Crossings Conf, Norway
At Radisson Blu Royal Hotel, Bergen. Organised by Norwegian Public Roads Administration and features extreme crossings and new technologies. For more details tel: +47 22 94 75 00, email siri.engen@tekna.no or see www.SC2013.no.

23-26 JUNE 2013
Rapid Excavation & Tunneling Conf (RETC), Washington DC, US
Wardman Park Marriott. Organised by the Society for Mining, Metallurgy & Exploration. For more details tel: +1 (303) 948-4200 or email: meetings@smenet.org.

BRITISH TUNNELLING SOCIETY

ALL BTS MEETINGS ARE AT THE INSTITUTION OF CIVIL ENGINEERS, LONDON, UNLESS OTHERWISE STATED, AT 17:30 FOR 18:00 UNTIL APPROX. 19:30. TRADITIONAL BAR AND SNACKS WILL BE AVAILABLE AFTERWARDS.

20 SEPTEMBER 2012
URUP - Ultra Rapid Under Pass - An innovative shield tunnelling technology
Makoto Kanai - vice-president - & Akhiro Nichimori - senior tunnel engineer, both of Obayashi, present the URUP shaftless shield method, especially for congested area, challenging ground conditions and stringent physical and environmental constraints. The presentation will describe how the URUP concept was developed, mechanisms of ground control under shallow cover and review projects where it has been successfully used. The critical issues in ‘URUP’ technology are tunnel face stability and ground movement control. Innovative methods are used that have been developed through extensive technical research and development.

OCTOBER/NOVEMBER
Annual Health & Safety Course
At ICE, London. Details to be announced.

4 OCTOBER 2012
BTS Young Members: Numerical modelling
Speakers: Anmol Bedi (Imperial College, London), Panagiotis Spyridis (Dr. Sauer & Partners) and Angelos Gakis (Dr. Sauer & Partners).

1 NOVEMBER 2012
BTS Young Members: AGM and Design of openings in tunnels and shafts

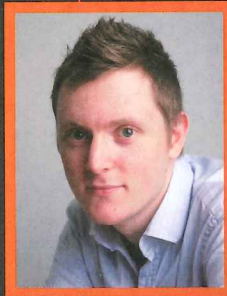
18 OCTOBER 2012
Tunnel Security and Blast Analysis
Blast protection design of transport tunnels. Speaker to be announced.

15 NOVEMBER 2012
EPBM & Slurry Tunnelling Principles
Safe operational protocols for full-face TBMs. Speaker to be announced.

13 DECEMBER 2012
Debate: ‘This house believes tunnel projects in the UK are over-staffed and over-specified’

A DATE TO REMEMBER...
If you know of a tunnelling related conference, event, seminar or exhibition, which is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Editor, ‘Tunnels & Tunnelling International’, Boundary House, 91-93 Charterhouse Street, London, EC1M 6HR, United Kingdom. Fax: +44 20 7936 6826 Email: editor@tunnelsandtunnelling.com Web: www.tunnelsandtunnelling.com

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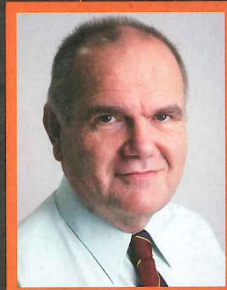
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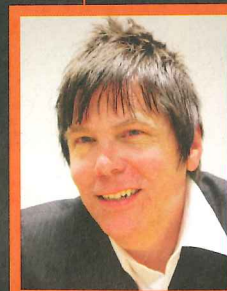


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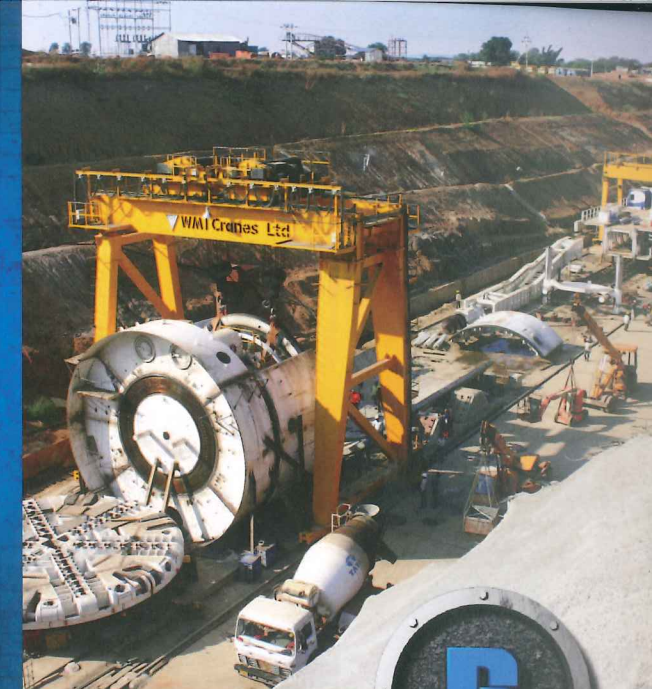
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