JULY 2011

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At the cutting edge

India's first slurry TBM launches for the Bangalore metro

ST. PETERSBURG: CLEVER ALONG THE NEVA RIVER.

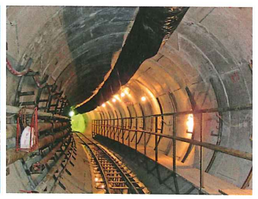
The million-strong Russian metropolis St. Petersburg is investing in a new, efficient sewage system. An almost 1,200 meter long tunnel with a connection to the urban main collector is under construction along the Neva River. Engineers faced a special challenge: a disturbance zone with quicksand, measuring about 100 meters in length, which formed part of the route, otherwise mainly consisting of hard loam. Therefore, two conveyor systems were required in this project to guarantee safe tunnelling operations.

For this reason, a "Herrenknecht Combined Shield" was deployed. The innovative machine configuration allows the machine to be changed easily between TBM mode with belt discharge and slurry mode. After 500 meters of tunnelling, the crew switched the machine from TBM mode to slurry mode so that the disturbance zone with a maximum groundwater pressure of up to 7.25 bar could be safely crossed. Here, the excavated material was transported with the help of pump stations. The last leg of around 600 meters was then excavated again using the TBM mode.

The tunnel construction team of OOO STIS Ltd. achieved breakthrough on April 14, 2011. The successful cooperation between contractor, client and engineers in this challenging project showed once again that teamwork and closely interrelated technical solutions form the basis of top performances in constructing underground infrastructures.

ST. PETERSBURG | RUSSIA

PROJECT DATA	CONTRACTOR
M-1360M **TBM HCS3700AH** Diameter: 4,596mm Max. torque: 2,400kNm Tunnel length: 1,162m Geology: loam, quicksand, boulders	OOO STIS Ltd.



comment

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Call for papers

First of all, I would like to make a quick apology for the late delivery of this issue, I hope it made it to you in time to get in your suitcase and you're now sat on a beach reading this, enjoying your summer holidays. We're running a week behind on this issue as we've been trekking all over the place to take part in the busy spring conference season.

From the World Tunnelling Congress in Helsinki to the Rapid Excavation and Tunneling Conference in San Francisco and the Underground Construction exhibition in London, it has been a busy season. And, in many hotel lobbies and bars over the past months there has been a begrudging of all the events for crowding the diary, but enough has been said about that over a glass or two and I've already blogged on it too (this is where I plug the newly launched blog on tunnelsandtunnelling.com, so check that out along with my twitter feed @TunnelsEditor).

But there is no denying that some great papers were delivered, useful knowledge transferred and new contacts made – and that is why these events are held.

And this brings me to my second comment. *T&TI* has long been a trusted source of reliable technical content. It has kept the industry informed of long lasting papers that get reprinted round the globe and advance tunnelling None more so than the O'Reily-New paper first announced in the May 1982 issue of *T&TI* and which led to the widely used New-Bowers paper. It has also brought the most in-depth reports of the greatest tunnelling projects, achievements and challenges through regular news coverage and reports.

And it continues to do all these things (Bowers is in this issue on page 42, O'Reily is scheduled for the September issue of *T&TI* and rumours have it New is working on a new paper, which we'll publish as soon as we have it).

As we move into the second half of 2011 it becomes time to start planning for next year. We'd like to hear from you. As we develop the plans for 2012 we'd like to feature the project you are working on, the system you are trialing, the method you are testing or the research you are carrying out. *T&TI* remains the best method for disseminating new ideas, breakthroughs, successes and lessons learnt. I hope you enjoy this month's installment over a beer by the barbecue or with your feet up by the pool!

Jon Young

contents

On the cover:
The Bangalore metro project calls on India's first slurry TBM

Lyon-Turin work forges ahead despite violent protests

FRANCE-ITALY

Police clashed with protestors at worksites in the Susa Valley, west of Turin in northwest Italy last month. The dissent was in response to construction work for the Lyon-Turin high-speed rail (HSR) link. It was the second time in seven days that unrest surrounded the project.

Police used tear gas against demonstrators on 27 June who had built barricades to prevent the start of construction. One tunnel worker and more than 30 police were injured.

Prior to the violence, some 3,000 people demonstrated peacefully, holding a prayer vigil through the night. Protests against the Lyon-Turin rail link, and 57km Mont d'Ambin base tunnel, have largely been on environmental grounds. Susa Valley is an area of outstanding natural beauty.

Lyon-Turin Ferroviare (LTF) – a subsidiary of French rail network owner and operator Reseau Ferre de France and Italian rail network owner Rete Ferroviaria Italiana – is the developer of the 'common Franco-Italian section' of the rail link, which includes the base tunnel itself.

A spokesman for LTF told *T&TI*, "Although many local towns back the project, there are some NIMBY protestors but also a large number of Italian anarchists. It was fortunate that there were few casualties in the clashes.

"There were about 6,000 protestors in the area of Chiomonte, Susa Valley. Italian police pushed back against new assaults of about 250 anarchists close to the building site of Maddalena, also in Susa. Our works are going on, and the main Italian institutions, Piedmont Region and several mayors of the area denounced the riots."

On the progress of the project as a whole, the spokesman added, "The main contracts for the construction of the base tunnel have, of course, not yet been awarded. Construction of the main tunnel is not expected to commence before 2013-2014.

"The survey works in the Maurienne Valley, France, were completed in mid-2010. At the moment, LTF is launching the survey works in Chiomonte, Italy, with the construction of the survey gallery of La Maddalena."

The spokesman added that, "Preparatory works costing EUR 1.5M (USD 2.18M) were entrusted by LTF to two local contractors, Italcoge and Martina. The majority of the work involved the construction of a fence around the building site. The total cost of the survey gallery of Maddalena is EUR 143M (USD 207.78M). The main contractor for excavation will be Italy-based company, CMC."

London Mayor calls for HS2 tunnels

GREAT BRITAIN

London Mayor Boris Johnson this month called for the entire High Speed Two (HS2) rail alignment in Greater London to be put through tunnels.

Johnson's announcement was made in response to an opinion poll that found nearly 50 per cent of the British public supported cutting funding for HS2.

The poll was conducted over the 20th and 21st of June by research body YouGov and political lobby group, the Taxpayers' Alliance.

Johnson wrote on his website, "It is perverse that a section of the route through Greater London, clearly affecting large numbers of people, has been subject to so little environmental mitigation.

"I am seeking substantial changes in design of the route to ensure these impacts are properly addressed, preferably by tunnelling the whole route through London. Without such changes I cannot support the current proposal."

A HS2 spokesman told *T&TI*, "About one third of the proposed route for HS2 from London Euston to the M25 would be in tunnels.

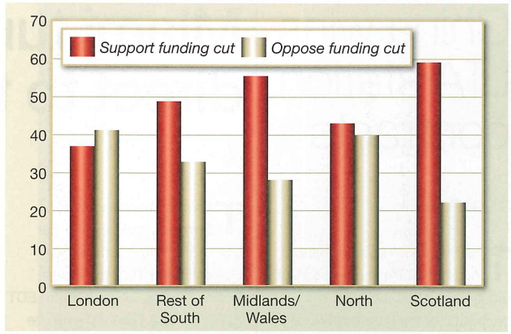
"As tunnels are much more expensive than routes on the surface, we have had to consider what offers the best overall value for money, taking account of the impacts of a route on the surface and the scope for mitigation."

The spokesman added that, "Where our proposals for the route are not in tunnels, HS2 is committed to ensuring that effects on local communities are kept to a minimum."

The exact result of the poll showed that some 34 per cent of the population supported HS2. With the 48 per cent opposed it showed that 18 per cent, or nearly one fifth of the country was unsure of its opinion.

The HS2 public consultation period was due to end on 29 July as *T&TI* went to press.

Right: The opinion poll revealed that Scotland was the region most in support of cancelling funding for the HS2 project



San Fran subway bid

USA

The San Francisco Municipal Transportation Agency (SFMTA) awarded a contract worth USD 233M to a joint venture of SA Healy and Barnard on 28 June for the Central Subway extension.

Underground construction includes two single-track tunnels of 1.7 miles (2.7km), which will be excavated by two TBMs of 6.4m diameter and will include a one-pass precast segmental lining.

The Central Subway extension will provide rail services to Chinatown and connect to existing commuter rail lines BART and Caltrain.

There are three underground station contracts yet to bid in late 2011 or early 2012. The fourth station will be surface level.

New player wades in on Tideway

GREAT BRITAIN

A commission was set up on 4 July to probe the Thames Tunnel 'super sewer'. Commission chair Lord Selbourne has struggled to find an engineer to join the board who is "firstly not on the payroll of Thames Water, and secondly unafraid of being blacklisted for speaking against the project," a Hammersmith and Fulham (H&F) spokesman told *T&TI* this month.

"There is one spot, the fifth, on the Thames Tunnel Commission that has yet to be filled. [...] It will take someone either very brave, or possibly an engineer from abroad to step forward," she added.

The commission was set up and sponsored by four riverside boroughs: Hammersmith and Fulham, Kensington and Chelsea, Richmond, and also Southwark. Lord Selbourne expected the cost of investigating the Thames Tunnel to be GBP 20,000 (USD 32,000), which was covered equally by each borough.

The H&F spokesperson told T&T that the idea of the commission partly originated from criticism by the Environment, Food and Rural Affairs (EFRA) select committee of Thames Water for "not properly evaluating alternatives". The spokesman added that the first phase of public consultation was purely related to the alignment, without discussing other solutions as will be the case in phase two.

H&F council leader Stephen Greenhalgh said, "Doing nothing is not an option, but we need to consider the possibility that there are better alternatives. On a recent trip to Chicago I heard how few cities are approaching it in this way – many realise that a tunnel-only option is not the best solution."

Both sides have given their backing to the Commission. A Thames Water spokesperson told T&T, "We agree that [the CSOs] must be resolved at minimum cost, so we welcome the appointment of this commission and [will provide] whatever information and assistance Lord Selborne and his colleagues may require."

The H&F spokesperson added, "In two months the Commission will report back with their assessment of the problem, and give their decision on the best course. If they decide that the tunnel is the best option, we will just have to live with it."

Also named as members of the Commission were Richard Ashley, professor of urban water at Sheffield University; Kaid Benfield of the Natural Resources Defense Council and Andrew Whetnal of the Consumer Council for Water.

Phase two of consultation should begin in September.

News in brief

Stuttgart rail contracts under threat of delay
Capacity tests on the estimated EUR 4.1bn (USD 5.9bn) Stuttgart 21 high-speed rail project may not go ahead as scheduled, as simulations may overrun, possibly delaying the award of tunnelling contracts worth EUR 750M (USD 1.07bn).

Ottawa issues LRT RFQ
The City of Ottawa issued an RFQ on 30 June to design, build, finance and maintain its proposed light rail project from Tunney's Pasture to Blair Station, including a 3.2km twin-bore tunnel. The deadline is 13 September, 15:00. The city currently estimates the contract at USD 2.1bn.

China wins LTA station contracts

SINGAPORE

The Singapore Land Transport Authority (LTA) announced last month that it had awarded two contracts for the Downtown Line Stage Three (DTL3) project to the China State Construction Engineering Company (CSCEC).

The contracts, C929 and C932A, totalled SGD 216.8M (USD 174.94M) and were for construction works on the Kaki Bukit (C929) and Kallang Bahru (C932A) stations. LTA said that CSCEC had extensive experience in railway construction projects in China, though these were the company's first MRT civils contracts in Singapore. Construction is scheduled to begin in July for completion in 2017.

Miami tunnel TBM delivered direct to the Port

USA

The ship that departed Germany loaded with the USD 45M, 13m-diameter Herrenknecht TBM arrived in Miami, Florida, US at 6.30pm EDT (UTC -5). The TBM will execute the seven-month eastbound tunnel drive from Watson Island to Dodge Island on the Port of Miami Tunnel Project.

The ship entered Miami through the man-made shipping channel, Government Cut and delivered the machine to contractor, Bouygues Civil Works of Florida.

Once unloaded from the ship, the TBM will be moved to a ready-prepared pit on Watson Island. A spokesperson for the project told *T&TI* that the assembly should take around three months. Excavation will commence in October.

Residents had the opportunity to photograph the arrival from near Miami Beach.

Above: The trans-Atlantic voyage came to an end last month when the 13m-diameter Herrenknecht TBM arrived in Miami's port

NSW M2 tunnel widening will pay dividends

AUSTRALIA

The Norfolk tunnel on the M2 motorway in northwest Sydney, New South Wales, Australia will be widened to accommodate three lanes of traffic and one breakdown lane in each direction.

The May 2010 M2 Upgrade Environmental Assessment showed the need for works, which will go on around the clock through the tunnel section, expected to be the most challenging portion.

Works will include widening the rock walls, rock bolting of the existing tunnel to shore up the new, wider span and pin the secondary lining and the provision of new electrical and service trenches. The east and westbound tunnel tubes were both found to be in good geotechnical condition and works have been scheduled to take approximately 26 months.

"This AUD 550M (USD 588.94M) project will deliver more than AUD 1.7bn (USD 1.82bn) in economic returns to the people of New South Wales," said Mark Birrell, chairman of infrastructure lobby group Infrastructure Partnerships Australia.

"The partnership between [New South Wales government agency] the Roads & Traffic Authority and [the toll road owner and operator] Transurban, means that it will be delivered at no additional cost to the taxpayer.

Birrell added, "This project shows that private investment is available to bridge the gap in public infrastructure."

Costs to fight cancelled tunnel exceed USD 1M

USA

New Jersey's legal fees to fight its USD 271M bill from the federal government for the cancelled ARC tunnel passed USD 1M, it was announced in June.

The state attorney general's office released invoices for legal work of USD 72,588 done in March, and another USD 54,000 in April.

Washington D.C.-based law firm Patton Boggs billed the state USD 950,000 in December 2010 when it was retained to fight the federal government's bill after governor Chris Christie cancelled the tunnel in October, over the concern of cost overruns.

New Jersey spent USD 610M on preliminary engineering and design for the tunnel before its cancellation, with USD 271M from the Federal Transit Administration.

News in brief

Airport Link TBMs make final breakthrough
Two TBMs each excavating 2.5km tunnels on the Toombul to Lutwyche section of Brisbane's Airport Link project broke through on 4 and 6 July. The machines' cutterheads and shields will be buried below the tunnels.

Breathtaking end to Brighton sewer

GREAT BRITAIN

Excavation was completed last month on the new sewer tunnel between Brighton Marina and Friars Bay in Sussex, UK. The 2.44m Lovat TBM named Alice broke through to Portobello on 22 June after a 3.6km drive.

The drive was part of the Cleaner Seas for Sussex project undertaken by contracting JV 4Delivery on behalf of client Southern Water.

The sister machine, named Hollyblue, completed its 1,052m drive from Peacehaven to Friars Bay in May. Previously, Alice executed a 1.8km drive between Ovingdean and Marine Drive while Hollyblue bored 2.7km from Peacehaven to Portobello.

A spokesman for Southern Water told *T&TI*, "Alice achieved a maximum advance rate of 32 rings in a shift while Hollyblue achieved 37. Long-term average from launch to breakthrough varied, as it was partially dependent upon drive length.

"Hollyblue's Peacehaven to Portobello drive achieved a maximum rate of 10.5m/shift while the Peacehaven to Friars Bay drive achieved 11.5m/shift. Alice's Ovingdean to Marine Drive (Belt Conveyor) bore achieved 12.6m/shift while the Ovingdean to Portobello (Screw Conveyor) bore achieved 14.8 m/shift."

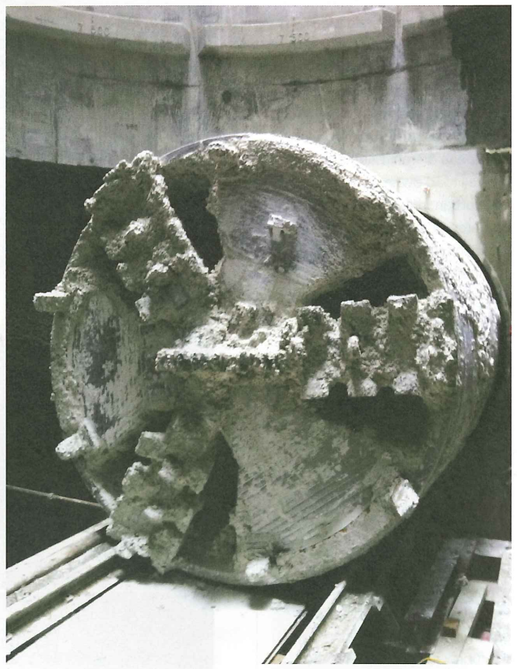
The spokesman added that although most of the ground was chalk with flints, spoil from near solution features also indicated the presence of some iron minerals.

Angus Mackenzie, tunnel agent at the Peacehaven Site said, "Hollyblue ultimately performed the best simply because it was specifically designed to excavate chalk with water pressures. In order to excavate in dry chalk the TBM operator had to add water under pressure. This was not required with Alice, which is a more general purpose/utility machine.

Mackenzie added, "Peacehaven to Portobello and Ovingdean to Marine Drive presented no untoward challenges as such, just the normal day-to-day trials and tribulations. Peacehaven to Friars Bay was interesting as the reception shaft was very congested with equipment relating to the pipejack [see *T&TI* April, p.33] that could not be disturbed by the TBM entry.

"Ovingdean to Portobello had a series of very sharp curves, the last one finishing 4.5m from the reception shaft.

Mackenzie finished with the comment, "The skill involved in straightening the TBM out and entering the shaft in the correct place is breathtaking."



Right: With Alice's breakthrough, only a few connections remain to be made. Construction should be completed this year

News in brief

Another call to Helsinki
The International Federation of Municipal Engineering issued a call for papers for its 2012 World Congress in Helsinki, 4-10 June. The theme is 'Sustainable Communities' and the deadline for paper abstract submission is 30 September. See www.ifme2012.com.

Mexico City's metro TBM halfway through excavations
The Robbins EPB machine excavating the 7km bored tunnel portion of Mexico City's Line 12 arrived at Parque de Los Venados Station on 29 June, completing a total of 4,340m since its launch in February 2010.

Gaza tunnel collapse death
Palestinian tunneller, 22-year-old Sami Al-Nadi, died on 6 June in a tunnel collapse on the Gaza-Egyptian border, close to Salah El-Din gate.

Gallagher calls for technological consultancy
UK-based contractor Joseph Gallagher presented its senior tunnellers with iPhones last month. The technological development baffled some tunnellers, who had to call in specialist help from their offspring to resolve the issue and provide further training.

Crossrail takes possession of academy

GREAT BRITAIN

Crossrail officially took possession of the new Tunnelling and Underground Construction Academy last month, said Terry Morgan, chairman of Crossrail. Speaking last month at Underground Construction 2011 in the Earls Court conference centre, Morgan said that the GBP 50M (USD 80.1M) investment was a statement of Crossrail's legacy to the British tunnelling industry.

"Every GBP 3M (USD 4.8M) in contracted work will result in an output from the contractor, for example an apprentice position," said Morgan.

A spokesman for the academy later told *T&TI*, "The key here is that it is industry and demand-led. It will suit the changing needs and requirements of the industry. We should see the first courses starting in September."

BTS chairman Bob Ibell said, "It is sadly the case that training and apprenticeships have been neglected for too long. The academy is one of a number of measures set to correct this."

The Crossrail academy was built at Aldersbrook Sidings in Newham, London.

Record win at Qinling

CHINA

Robbins claimed this month that one of its machines had broken the record advance rate for a TBM in the 10-11m range. The TBM was on the Qinling rail project in China when it broke the record. The previous advance record, also set by a Robbins machine, was set on the Tunnel and Reservoir Plan (TARP) in Chicago, USA.

The new 841.8m advance record was set in April, with a peak 235m set in week 15 by the 10.2m main beam TBM that was commissioned by contactor China Railway Tunnel Group (CRTG) 18th Bureau in December 2008. Upon arrival it began boring one of the 16.6km parallel tunnels through Qinling Mountain.

A Robbins spokesman told *T&TI*, "The TARP tunnels were all in Dolomitic Limestone, with strengths ranging from 103 to 222 MPa UCS. Ground at West Qinling is phyllite and limestone, ranging from 30 to 100 MPa UCS.

"While the rock is softer at West Qinling, the tunnel depths vary greatly between the two projects. The majority of the TARP tunnels are approximately 90m below the city of Chicago. The amount of cover at the West Qinling tunnels, at the time of the record rates, was approximately 1,000m.

The spokesman added, "The TARP record was set by a 10.8m main beam TBM between 1989 and 1990.

"Although both are Main Beam machines, the TARP machine was fitted with 17-inch front-loading disc cutters, while the West Qinling Machines are fitted with back-loading 19-inch disc cutters for longer cutter life in rock and more efficient cutter changes.

"The West Qinling machines are also designed with the specialised ground support system replacing roof shield fingers while the TARP machine had roof shield fingers.

Construction contracts were awarded to CRTG 18th Bureau for the 'Left Line' tunnel and the China Railway Construction Corporation for the 'Right Line' tunnel.

News in brief

Indian pumped storage
Indian contractor HCC and Germany-based Alstom were awarded a USD 414.86M contract to construct the Tehri pumped storage plant in Uttarakhand, north India.

Victoria Park tunnelled
The Victoria Park tunnel in Auckland, New Zealand was completed this month. The 15-month project was completed three months early.

LTA awards C926 and C927
The two Singapore DTL3 contracts worth USD 345M were awarded to Italian contractor CMC di Ravenna.

Record rate on Prague metro extension

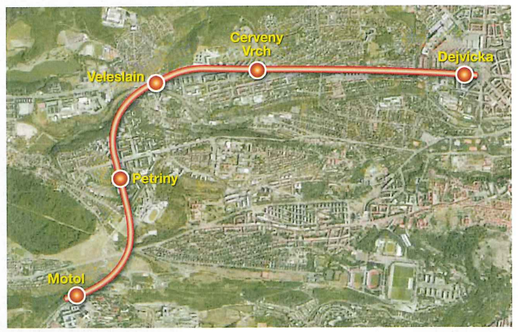
CZECH REPUBLIC

The TBMs requisitioned to excavate the Prague metro fifth extension, Line A, achieved a record advance rate last month. The day shift advance of six 1.5m rings, combined with a seven-ring night time advance resulted in an advance rate of 18.5m over 24 hours, significantly higher than the average anticipated advance rate of 12m per day.

The northwest extension beyond the existing Line A extremity Dejvicka Station will contain four stations, Cerveny, Vrch, Veleslavin Petriny and Motol, to be excavated by NATM, which will also be used to excavate the double-track running tunnels to Motol Station. The other tunnels, both of 4.05km, were designed as single track and to be driven by EPBM. A Metrostav spokesman said that this method was chosen as it had less impact, as well as being safer and quicker.

The 6.08m-diameter Herrenknecht full-face shield EPBMs, named Tonda and Adela by young patients of the Clinic of Paediatric Surgery at Motol, were equipped with 17 twin-disc cutters, as well as four single-disc gauge cutters that can be extended to increase the excavation diameter to 6.1m.

Right: The Line A extension will expand the line from the current extremity Dejvicka Station to a new station at Motol



The cutterhead was designed by Herrenknecht to allow the switching of cutter discs with soft ground rippers, which were equipped as *T&TI* went to press. Three crews of eight were employed by Metrostav to operate the machines.

Muck is transported via a screw conveyor to a belt conveyor behind the tunnel.

Excavation of the single-track running tunnels kicked off in April following machine assembly in prepared beds at the bottom of a 21m-diameter, 34m-deep shaft braced by secant piles. The shaft was located at the BRE1 construction site to the east of the Vypich intersection. Tonda began the drive on the left-hand tunnel tube from the drive direction. As *T&TI* went to press, Adela was due to proceed, with a three-month lag time, in July.

UK first LED lit tunnel

GREAT BRITAIN

The Upper Thames Street road tunnel has become the first LED-lit tunnel in the UK, Transport for London (TFL) said last month.

The lights will last 20 years compared with two years for conventional lighting. Costs were projected to fall from GBP 50,000 (USD 81,040) to GBP 10,000 (USD 16,208) per annum. The lights will save 163 tonnes of CO2 annually.

Some 268 lighting strips were installed following testing procedures and will be monitored for around two or three months before TFL decides whether or not to proceed with further installation on other tunnels.

The lighting system was manufactured by UK-based lighting manufacturer Indal WRTL and installed by mechanical, electrical, instrumentation and industrial contractor SPIE WHS for Ringway Jacobs, TFL's highway maintenance contractor.

First orders for Seli-Kawasaki venture

ITALY-JAPAN

The Seli-Kawasaki partnership has borne fruit, Seli announced last month. One year in to the five-year agreement, the order for a combined total of five TBMs to excavate the Bangalore, India and Copenhagen, Denmark metro projects was the first received by the combined team.

The EPBMs were designed to face hard rock as well as alluvium soils, with the cutterhead designed by Seli to be efficient in both types of ground. As per the partnership agreement, Seli manufactured the TBMs while Kawasaki Heavy Industries (KHI) supplied the cutterhead supports, drives and the screw conveyor. The TBMs as a whole were jointly designed.

"One of the main technical features is the new cutterhead support and main drive system developed by KHI with Seli cooperation," a Seli spokesman told *T&TI*. "This allows the machine to be operated in EPB mode at a wide range of cutterhead speeds, meaning high speeds are possible in hard rock and low speeds in soft ground.

She added, "The philosophy behind the agreement is not only to create an industrial economy through production sites in Japan and Italy, but also to ensure a quality product with technology far beyond the competition, where widespread use of components made in China is less focused on innovation and overall quality."

Above: Seli and Kawasaki signed the partnership last year

Goodfellow joins Aldea

USA

Bob Goodfellow last month joined US-based Aldea Services as senior vice president. Goodfellow joins vice President Mohamed Younis and President Gina Goodfellow in the recently formed tunnelling and geotechnical engineering firm.

The firm, which made its debut at the Rapid Tunnelling and Excavation Conference in San Francisco last month aims to establish itself as an international consulting firm and plans to grow to half a dozen employees in the coming year.

"We are all very excited to be working together again under the Aldea Services banner," said Bob Goodfellow. "We plan to create a brand with Aldea Services that means high quality and integrity wherever we work in the world."

The company, which is 100 per cent owned by Gina Goodfellow, Bob's wife, will focus on winning work in North America for the first year and aims to become involved in international projects as the company grows.

The company offers services in design and construction management for underground projects. It also argues it can deliver expertise in management of risk and delivery of underground projects.

Hayward Baker promotions

USA

North American geotechnical contractor Hayward Baker announced last month that it had made a series of promotions and appointments to its leadership.

Jeffrey Hill was promoted to central region business development manager, tasked with future development of closer relationships with engineering and construction companies. He will also provide assistance to the Chicago, St. Louis, Dallas, Houston, Denver and Minneapolis offices. Hill is an expert in mine stabilisation, earth retention, micropile and grouting projects.

Gregory Terri took over from Hill as area manager of St. Louis. Hayward Baker said that his appointment brought geotechnical skills as well as experience in earth retention and piling.

Todd Ross was made the new area manager of Utah and will establish the firm's newly opened Salt Lake City office. His duties will cover securing new projects and building Hayward Baker's local reputation. Ross was previously a project manager.

News in brief

Sandvik publishes quarterly figures
Swedish equipment manufacturer Sandvik will this month announce that it took SEK 24.9M (USD 3.9M) in orders in the first quarter of 2011. The order intake is down from SEK 26.3M (USD 4.1M) in Q4 but up year-on-year from SEK 22.3M (USD 3.5M). Operating profit increased drastically year-on-year from SEK 1.9M (USD 0.3M) in Q1 2010 to SEK 3.3M (USD 0.5M) in 2011. The full report is due to be published on 19 July.

Atkins announces profit growth in annual report
UK consultancy giant WS Atkins last month announced profit increases in its preliminary annual report ending March 2011. Underlying operating profit was up 7.5 per cent on 2010 figures, increasing from GBP 110.4M to GBP 118.7M (USD 176.5 to USD 189.7M). The firm said, "Integration of a strategic acquisition in North America has progressed well and the business is performing in line with our expectations."

John Holland opens Adelaide office
Australian contractor John Holland last month opened a permanent office in Adelaide "as part of its ongoing commitment to South Australia and planned future growth," said a spokesman. John Holland's ongoing projects for South Australia's Department of Energy, Transport and Infrastructure include the Rail Revitalisation Project – Belair Line and South Road Superway, the biggest single investment in a South Australian road project and the state's most complex engineering road construction project to date.

Dywidag Systems International sold

GERMANY

Munich-based civils and construction supplier, Dywidag Systems International (DSI) announced last month that it had been sold by US-based joint owners Bank of America Merrill Lynch and Barclays Capital to European private equity investment firm Triton.

"The new owner is both interested and dedicated to the success of DSI," said DSI chairman and CEO Alan Bate. He added, "It is also clear from customers, suppliers and partners that our new found ownership and financial stability is welcomed. We also see this manifest in new approaches to work with DSI on projects and programs."

Bank of America Merrill Lynch and Barclays Capital took over DSI in 2010 from CVC Capital Partners, though funds advised by CVC remained significant shareholders and continued to be represented on the board, according to a DSI announcement in April last year.

A spokesperson for Bank of America Merrill Lynch and Barclays Capital said at the time, "We share CVC's confidence in DSI and are anxious to support management's plans to develop the business going forward."

A spokesperson for DSI told *T&TI*, "There will now be a period of homework for Triton as they learn the structure and business of DSI. This is the third private equity investment firm that has had ownership of DSI, so it is not a new experience – there shouldn't be a serious impact on DSI's day-to-day running."

News in brief

NFM Technologies appoints new CEO
Alan Deleard, 53, has been appointed the new CEO of French/Chinese TBM manufacturer NFM Technologies. Deleard replaces Luc Devaux. Before joining NFM Technologies in 2008, Deleard worked in industrial companies in the packaging and automotive sectors.

Atkins director and committe chair retires
UK consultant WS Atkins last month announced that Sir Peter Williams, a non-executive director and chairman of the Remuneration Committee, will retire from the Board of Atkins following the conclusion of the Company's annual general meeting in September. Sir Peter joined the Atkins Board in May 2004.

Putzmeister launches support hotline
Putzmeister Iberica, Madrid has established a 24-hour/seven days technical service hotline for emergencies, available to all customers requiring troubleshooting or technical assistance. Available in English via +34 91 428 8100.

Tutor Perini to acquire Lunda...

USA

US-based Tutor Perini announced last month that it had signed a letter of intent to purchase a 100 per cent share of Lunda Construction Company.

"Lunda Construction is one of the most successful civil contractors in the United States," said Ronald Tutor, chairman and CEO of Tutor Perini. "[This decision] represents our expansion into the Midwestern markets. They have a resume of experience which complements our operations, and we in turn will be in a position to support their growth objectives in their existing markets."

The final price will be subject to an adjustment based on the net worth of Lunda when the deal is closed.

Lunda will continue to operate under the current company name and will continue to be managed by its current senior management team. Larry Lunda will remain as president and CEO.

...and Frontier Kemper

USA

Tutor Perini announced last month a full acquisition of US-based Frontier-Kemper Constructors from Deilmann Haniel International Mining and Tunneling.

Under the terms of the transaction, Tutor Perini acquired 100 per cent of Frontier-Kemper's stock for approximately USD 61M in cash and assumed approximately USD 52M of debt, of which USD 35M was paid off at closing. Tutor Perini financed the transaction with proceeds from its senior note offering that closed in October 2010.

Frontier-Kemper will continue to operate under its current name and will be managed by its current senior management team, with W.D. Rogstad remaining as president and CEO.

Rogstad said: "We are eager to leverage Tutor Perini's national presence and civil expertise to expand our reach and capture new opportunities."

Frontier-Kemper currently has a backlog of approximately USD 300M. Current projects include part of a JV with Traylor Bros for Sound Transit's University Link light rail extension in Seattle, and the Granite/Traylor/Frontier-Kemper JV for the construction of the Eastside Access Queens Bored Tunnels in New York.

Ronald Tutor, chairman and CEO of Tutor Perini, said last month that, "Frontier-Kemper is an ideal fit for [Tutor Perini's] civil business and will significantly bolster our tunneling business in the United States and expand our reach into Canada."

BB sells Fru-Con to BB

USA

The US Construction Services Division of Balfour Beatty announced on 17 June it had acquired Fru-Con Construction LLC from Bilfinger Berger for a net cash sum of USD 20M.

Virginia-based water services contractor Fru-Con enjoyed annual revenues of around US 80M last year.

Balfour Beatty chief executive Ian Tyler said, "The acquistion of Fru-Con is a significant step in expanding capabilities in the attractive US water market." It will promote Balfour Beatty growth in the mid-Atlantic and California markets primarily, plus the Carolinas, Georgia, Florida and Texas.

Fru-Con was founded in 1872 and at the time of the deal had 150 employees working on major plant projects in Maryland and Virginia, and completed the award-winning USD 136M Water Pollution Control Plant Upgrade and Expansion project in Arlington, Virginia, last year.

Bilfinger Berger sold other assets recently, which included Australian subsidiary Valemus Australia in March. The stated aim was to use the funds to further expand its services activities and increase scope for investment.

Divine intervention for thorny Singapore drive

The Singapore Land Transport Authority announced last month that tunnelling had begun at the Beauty World Station and associated tunnels on the Downtown Line Two (DTL2) metro project.

Australia-based McConnell Dowell was awarded the design and construction contract, C916, for the two 6.6m o.d., 1km-long twin bore tunnels from Beauty World to King Albert Park station in March 2009. Full scope of works to be undertaken includes two cross passages, station box structure, shaft, recharge wells and diversion structures.

The Beauty World site is located in the Bukit Timah district of Singapore, some 15km from the central business district.

The area contains established businesses as well as shopping centres and residential areas with a densely concentrated population. The Bukit Timah Road runs through this area.

"To divert the road was a complex problem," said Thomas. "It involved temporary structures that span and remain over the main station box and cross-over structures during construction.

"The structures are comprised of steel decking beams and panels and a composite concrete beam structure. As well as providing vehicle and pedestrian diversions, they also provide a working platform at grade level for construction equipment."

Two Herrenknecht mixed shield TBMs called Artemis and Athena – Greek goddesses of the hunt and heroic endeavour respectively – will be used on the project. The machine diameters are 6.6m. The mixed ground cutterhead was fitted out with backloaded disc cutters, scrapers and reamers. It was set up with four twin ring centre cutters, 24 face cutters and 15 gauge cutters.

"The launch shaft is an annex to the station structure and will provide the interface connection between the bored tunnels and the station," said Thomas. "The shaft will not only facilitate the installation, assembly and excavation of the bored tunnels but will also provide a temporary staging area for the track work contractor once tunnel and station structures are complete."

Concrete formed secant piles of 0.9 and 1.2m were used as an earth retaining support system for the shaft. No drilling fluids, such as bentonite or polymer, were used during pile installation. This saved space on the congested work site.

"Spoil is excavated using a telescopic excavator and conventional muck skips," said Thomas. "Rock excavation requires initial breaking through controlled blasting, chemical splitting, hydraulic splitting and excavator hammer breaking.

"Geology consists of the alluvial member of the Kallang formation. This typically consists of sands, silts and clay through to cohesive soils including silt, clay, sandy silt and sandy clay.

"This is underlain by Bukit Timah Granite. Bukit Timah Granite is a major, and one of the oldest geological formations in Singapore. The formation is 200-250 million years old and varies from granite to granodorite with various weathering stages from fresh to completely weathered residual soil."

Bukit Timah Granite has an average ultimate compressive strength of approximately 180MPa.

It was expected that groundwater would be encountered in the Kallang formation. This will be addressed with a series of recharge wells that will compensate for groundwater loss to prevent consolidation and settlement.

TBM equipment selection was a crucial risk mitigation strategy for the mixed face conditions that have been identified. The speed with which the face conditions can/will change is unique.

DTL3, which is currently being tendered by many contractors, appears to offer more favourable tunnelling conditions than are present on DTL2. The Beauty World Station project involves arguably the most challenging tunnelling conditions for DTL2.

It was expected before works began that face conditions would comprise 52 per cent full face soil, 18 per cent mixed ground and 30 per cent full face rock for the Beauty World Tunnels.

Alex Conacher

Shinagawa drive exceeds rate expectations

Excavation rates on the Tokyo Expressway have smashed expectations by more than 150m. Boring on the westbound tunnel of the Shinagawa section of the project broke 550m in April against an already high target rate of 400m per month.

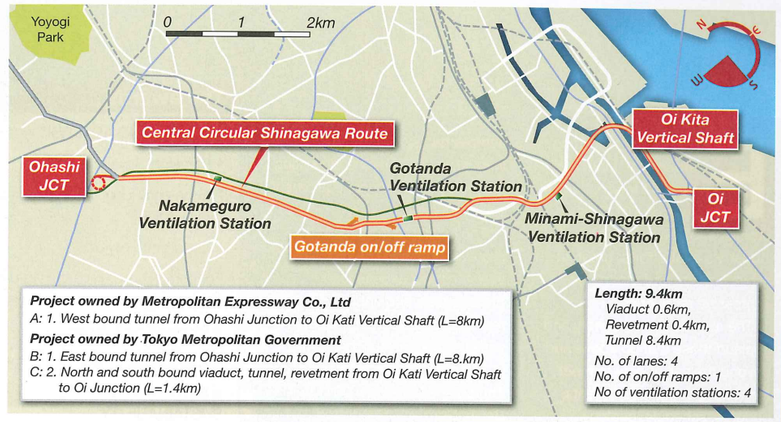
"To reach and exceed this goal, we adopted several innovations to reduce the cycle time of excavation," a spokesperson for client Metropolitan Expressway Company (MEX) told *T&TI* last month. "The system that enables the assembly of segments during excavation was used, rather than the conventional method, in which the segments are generally assembled after excavation. Also, segments of the greatest previously used width, 2m, were employed."

Construction of Shinagawa section of the Central Circular Route on the expressway was broken into three contracts. The 8km westbound tunnel from Ohashi Junction to the Oi Kita Vertical shaft was awarded to Japanese contractor Kajima. The second contract, the 8km eastbound tunnel on the same route, was awarded to Obayashi. The third contract for the 0.4km north and south bores from the Oi Kita Vertical Shaft to Oi Junction was also awarded to Obayashi.

As there are multiple stake holders in this project, MEX was designated the client for Kajima's contract while the Tokyo Metropolitan Government was designated the client for Obayashi's contracts.

A 12.55m Kawasaki EPBM is cutting the westbound bore with a 12.3m external diameter and a 11.5 internal. The machine was chosen as EPBs have been used successfully previously in the area, according to the client.

As *T&TI* went to press the machine had been driven 4.5km through mudstone in the Kazusa Group that was found to be stiff and stable.



The MEX spokesman added, "To achieve such a large and long excavation, a large-scale cutter bit was used to eliminate the need to change the bit during excavation." Shinagawa project manager for Kajima, Masami Moriguchi, said that it is possible to change the bits if necessary, but that they are designed to last the length of the entire project drive.

Moriguchi added, "Constructing a large-diameter tunnel in a densely populated area is not uncommon in Japan. However, on this project, with a large diameter and great distance, total excavated volume is around 1M cubic metres, the same as a medium-sized earth dam. That's a lot of muck."

Work began on the JPY 400bn (USD 4.9bn) project in 2005 and will be finished in 2013. Other ongoing works as *T&TI* went to press included the connection to link the existing Central Circular Route Shinjuku section with the under construction Shinagawa section, an open cut excavation. MEX also told *T&TI* that there was no structural damage due to the 2011 Tohoku earthquake.

Alex Conacher

The 12.55m Kawasaki EPBM, chosen based on previous success

T&T International Awards 2011

Excitement is building around the launch of the *T&T* International Awards 2011, which promises to champion the industry's best efforts, greatest achievements and most impressive recoveries.

The awards aim to identify and applaud those that go above and beyond the call of duty to meet the testing demands of clients, budgets, schedule, geology and scope.

It is our pledge that these awards will not be a backslapping exercise for sponsors and supporters but instead will stand as a testament to the true achievements of tunnellers and an opportunity for others to learn from them.

The entry criteria has been published on our website: www.tunnelsandtunnelling.com and we will be publishing a complete list of the judging panels.

Over the coming months we will be seeking entries that demonstrate ground breaking achievements, as well as innovative use of new and existing technologies, methods, equipment and practices.

The judging panels are in the process of being pulled together from the most experienced professionals and unbiased representatives of committees, societies and institutions.

The event will be held on Thursday 8 December 2011 in Berlin, Germany. Shortlisted entries will be announced on 1 November and the list published in the November issue of *T&TI*.

A special awards supplement will be printed and distributed in Berlin and with the December issue of *T&TI*. The supplement will announce the award winners and also take a look at all of the shortlisted submissions.

All award entries are completely free of charge.

We hope you get involved by nominating your projects and colleagues for awards, by supporting the event and by joining us in Berlin!

Supported by:

BRITISH TUNNELLING SOCIETY

The awards

OVERCOMING ADVERSITY

• Foresight Award:

For the early identification and mitigation of a problem in design or construction

• Endurance Award:

For completing a project in the face of numerous or persistent challenges

• Tour de Force Award:

For successfully overcoming the greatest single challenge

SUSTAINABILITY

• Investor in Tunnellers Award:

For services to the education of tunnellers

• Preservation Award:

For tunnelling with the lowest impact on the environment through design or construction methods

• Lifetime Service to the Industry Medal:

For devotion and selfless service to tunnelling

INNOVATION

• Innovative use of Materials:

For the successful use of materials in unusual deployments

• Innovative use of Equipment:

For the successful use of equipment in unconventional deployments

• Innovative use of Instrumentation:

For the successful unusual use of instrumentation in site investigation, surveying or monitoring

Don't forget...

...to enter the 2011 *T&T* Photo Competition!

With the launch of the *T&T* International Awards 2011 the photo competition has been given an extension with entries being accepted until 1st October.

The final three shortlisted entries will be given a seat at the *T&T* table in Berlin and the winner will be presented with an all singing and all dancing digital SLR.

So get snapping and send in the image that best captures the tunnelling spirit.

tunnels & tunnelling ASIA

Incredible India

A thirst for water tunnels, soaring metro demand and grapples with health and safety

Final workshop acceptance of the 6.23m Herrenknecht gripper TBM for the Mumbai Water Supply IV project, Section A, on 1 March 2011 in Schwanau, Germany

CHENGDU: GREAT SUCCESS FOR THE METRO PIONEERS IN WESTERN CHINA.

Metro Chengdu
Line 1 Phase 1 and Line 2 Phase 1

- 21x EPB Shield
- 1x Mixshield
- Diameter: 6,250mm
- Cutterhead power: 945kW
- Tunnel kilometer in total: 50,3

After the first spade broke the earth in 2005, the city's officials – only five years later – are now launching operations on metro Line 1 in Chengdu, the first one in Western China. And the construction of the metro is continuing with giant steps in the 12-million-strong metropolis: Mechanized tunnelling in construction phase 1 on Line 2 was completed on June 8, 2011. By 2020, trains are expected to transport passengers through the city on seven lines over 151 kilometers.

Herrenknecht technology (EPB Shields and a Mixshield, Ø 6,250mm) has proved its efficiency in a total of 22 metro projects, and along more than 50 kilometers of tunnel in Chengdu. When designing the machines for Line 2, Herrenknecht engineers made use of the experience gained in Line 1. With an optimized opening ratio of the cutting wheels, they were better able to cope with the highly abrasive ground rich in gravel and water. The Herrenknecht S-401 crossed beneath the most difficult section of Line 2 – below Chengdu's Business Center – without any disturbances. In October 2010, the machine achieved a record stretch of 513 meters.

140 Herrenknecht machines have so far tunnelled almost 400 kilometers of metro routes in 14 cities in China.

Workers on the Bangalore metro kitted out in boots, hard hats and vests

photo © DS Photoworks

Safety thirst

Heath and safety in construction is improving in India as international companies and the National Safety Council make efforts to improve conditions. But there is still a long way to go, Jon Young visits India

Some 110m under the outskirts of Mumbai a dozen workers are excavating the launching chamber for a TBM drive towards the city. There are fears of terrorism attacks on the water supply and so Indian contractor Soma has been awarded the project to bury the above ground water pipelines.

The crew works an Atlas Copco ROC 203 drill rig to break out the rock and haul it up the shaft with a gantry crane and bucket. However, the shaft and the chamber are thick with smoke and dust. There is no sign of any ventilation for the workers, and after just a few minutes it becomes difficult to breathe. Workers wear dust masks, which offer little protection.

Soma general manager Vishnu Sharma later denies the absence of ventilation claiming: "We were using compressed air from the compressor unit which is at the top of the shaft. The tunnel ventilation fan station comprising motor size 110kW and two fans from Zitron were mobilised and put under operation during shaft & assembly chamber construction."

While on site in February, *T&TI* is told that ventilation would be installed once the TBM is delivered. The delivery of the TBM is significant to the organisation of the project. Soma is in charge of the shaft and launch chamber. It has subcontracted the tunnel boring to Herrenknecht subsidiary UTS, which takes control of the site after TBM arrival. Rajiv Sharma of Herrenknecht says ventilation will be installed for its bore.

It is no secret that the quality of health and safety on site varies wildly from project to project and county to country. And in India there is not the same pressure on health and safety as there might be elsewhere.

Aecom project manager for the Kolkata metro project Chris Schulz explains that Indian contractors need to bid in JV with an international partner to hit prequalification requirements. Sometimes it is only the presence of an international company on site that brings about better health and safety. But as contractors become more experienced, they will need less support.

National Safety Council

The National Safety Council of India (NSC) is making strong efforts to turn the tide on health and safety in the country. Entries for its annual safety awards closed last month. Along side the awards the NSC is publishing technical papers and offering training. In 2010 the NSC had more than 4000 participants in its safety courses.

India's construction market is booming as the country maintains the fastest growing GDP in the world. The tunnelling market is mainly fueled by demands for metro projects in the major cities – such as the Bangalore Metro (page 22) – spurred on by the success of the Delhi Metro, and water transfer projects such as the Mumbai Water Supply IV and the Alimineti Madhava Reddy (AMR) (page 28).

Bangalore's first bore

The first slurry TBM to be used in India has launched on the Bangalore east-west metro. Jon Young attends the launching ceremony

On a hot summers day in Bangalore, ambassadors, politicians, lobbyists, financers, press and the cream of the Indian tunnelling community crowd excitedly into a large marquee erected alongside the Majestic Station shaft eagerly awaiting the launch of the first slurry TBM to be used in India. Police patrol the site and line the sides of the tent. With one hand resting on their batons they survey the throng as Karnataka state Chief Minister Shri Yeddyurappa enters to a hail of applause, flash photography and genuine adoration from the baying crowd.

The guest list for the TBM launching ceremony on Bangalore's metro reads as a who's who for the Indian construction industry. Addressing this crowd Yeddyurappa proudly stamps his name on the project by congratulating those who have brought it this far. He is gifted with flowers and presents from the joint venture construction team. "The gods of the underworld must be very pleased," says the master of ceremonies. Following a ceremonial smashing of a coconut and lighting of fires the chief minister heads for the launch shaft and pushes the button that sets the cutter wheel in motion.

Yeddyurappa claims that the 6.44m Hitachi Zosen TBM is the first TBM to be used in a Southern Indian state and the first slurry TBM to be used in the country.

Bangalore east-west metro

As the third largest city in India, Bangalore faces congestion problems similar to those found in Delhi, Mumbai and Kolkata. Its population is growing at more than three per cent per annum with a record annual growth of 12 per cent. The 5.4 million residents place a massive demand on the limited public transport system. As a result, vehicle ownership is increasing. Some 1050 new vehicles are registered in Bangalore every day. But with high salaries in the 800 square km city, and multinational companies well established, the city can afford an upgrade.

There are two metro lines under construction in Bangalore, the north-south corridor and the east-west. A joint venture of Taiwanese contractor Continental Engineering Corporation (CEC) and Indian contractor Soma is executing the east-west line with the TBM starting works some 10 days after the launching ceremony last month. CEC's Indian arm CICI is carrying out the tunnelling works while Soma is excavating the stations.

The 4.45km of twin bore tunnels will be fully excavated by TBMs with the east and west ramps, the stations and a short pocket track being excavated by cut and cover. The tunnels will have a finished internal diameter of 5.6m, lined with precast segments 1.5m wide and in a five plus one arrangement. The segments are manufactured near the work site by Ya Li, part of Far Eastern Group.

The two TBMs will be staggered about one month or 50-100m apart and will have a minimum overburden of one diameter, though it is more typical along the alignment to have an overburden of around 10m.

Eastbound drive

Majestic station is the interchange station for the east-west and north-south lines. The contract for the station has not been awarded as the final costings for the project have not been agreed. There are some quiet concerns that this could slow the commissioning of the project but for now the focus is on the tunnelling works.

Project manager for CEC Russell Brown explains that the first 140m of the drive that TBM Helen is undertaking is among the most testing for the project. With a shallow overburden of just 1.5 diameters the TBM is carefully edging its way under the fragile buildings of Bangalore above. It is the only stretch of the project where the team were not able to keep all buildings outside the zone of influence. Nigel Butterfield, project manager for the general consultant says at this point the client, Bangalore Metro Rail Corporation (BMRC), will accept slight damage to local buildings, which must not exceed cracks of 5mm in width.

On the 960m drive eastbound from Majestic Station to Central College Station the TBMs will pass through stretches of silt, silty sand and highly weathered rock and hard rock at depths of 24m below ground. The drive should remain dry as the water table sits 4-7m below ground in this region.

To help keep within the permissible damage in the mixed face conditions, especially during the delicate first 140m, Ian Morrison from UK firm Mudtech has been called upon to develop a slurry capable of supporting the tunnel face during slow advance and that is able to keep the spoil in suspension (see box: Getting the mud right, page 25).

TBM Helen and TBM Margarita will reach Central College Station in September and October, says Brown. Soma is constructing the station but when the TBMs arrive the

Left: Lifting of the 6.49m cutterhead (all photos © DS Photoworks)

Geology

Generally a four-layer sub-soil profile has been noticed in the boreholes:

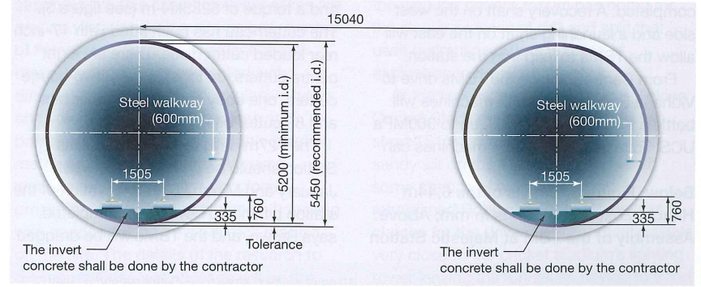
Layer-I: Over burden soil – Clayey silt/ sandy silt / silty sand (with clay binder)
This layer encountered at depths between 4.5 and 21m below existing ground level

Layer-II: Highly weathered rock
This layer encountered at depths between 4.5 and 27m below existing ground level

Layer-III: Moderately weathered rock
This layer encountered at depths between 9 and 21m below existing ground level

Layer-IV: Hard rock
This layer encountered at depths between 5 and 28m below existing ground level

Below, top: Figure 1, a typical cross section through the tunnel, units in mm; Below, bottom: Figure 2, a map of the north-south and east-west line, above ground in blue and below in red



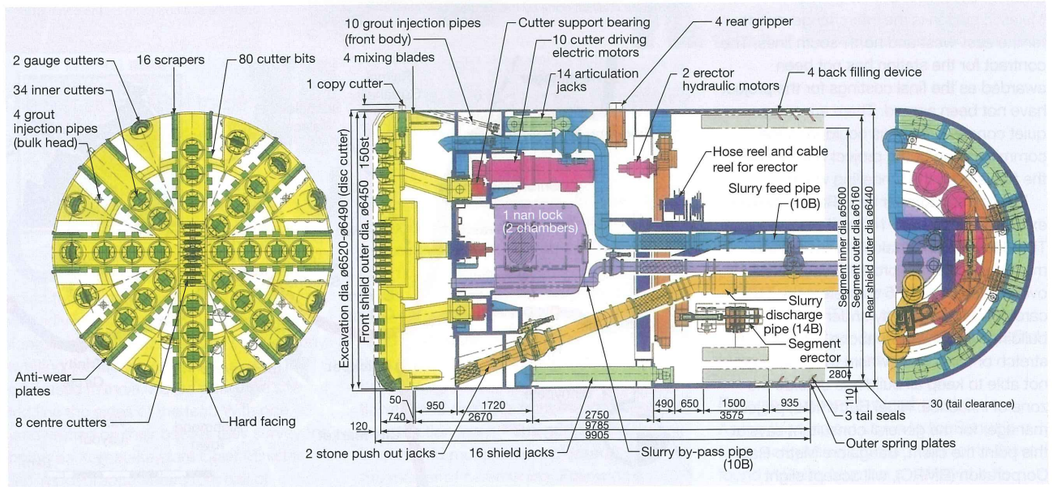
main excavation will not have been completed. A recovery shaft on the west side and a launching shaft on the east will allow the TBMs to leap frog the station.

From Central College the TBMs drive to Vidhana Soudha. The 350t machines will battle a full face of hard rock up to 300MPa UCS. To tackle the rock the machines can generate a propulsion force of 1160kN/m² and a torque of 6285kN-m (see figure 3). The cutterhead has been fitted with 17-inch rear loaded cutter discs. There are eight centre cutters, 34 inner cutters, two gauge cutters, one copy cutter, 16 scraper bits and 80 cutter bits.

The 727m drive to Vidhana Soudha Station should be completed between January and March 2012. Excavation of the station pit should have been completed, says Brown, and the TBMs will be dragged through to relaunch on the eastern end.

The final drive of the eastern leg for the two Hitachi Zosen TBMs will tackle the 479m run to Cricket Stadium Station. The drive will pass through clayey silt, highly weathered rock and hard rock. Brown explains, "At the drive from Vidhana Suda to Cricket Stadium there is lots of hard rock coming up into the face. It happens about five or six times and in particular one of the challenges for us is the last 200-300m. We come round a very tight 270m-radius curve

Below: Figure 3, Details of the 6.44m Hitachi Zosen TBM, units in mm; Above: Assembly of the TBM at Majestic Station



by the GPO building – a very ornate building with a large set of steps and columns to it. We sit right under the front facade of that building, it's right in our zone of influence."

BMRC stipulates that only negligible damage, defined as hairline cracks, is acceptable on heritage buildings. Passing through the mixed ground in close proximity to the GPO building, the tunnellers are going to have to carefully monitor subsidence as they pass through the curve.

Westbound drive

By the end of June 2012 the TBMs should have broken into the receiving shaft at Cricket Stadium. They will be dismantled and shipped back past the Majestic Station site to the west end of the pocket track for launch on the final short 227m drive. The pocket track is reversing siding that allows the trains to park off the main line. The 170m long track will be constructed using cut and cover and will be excavated using drill and split.

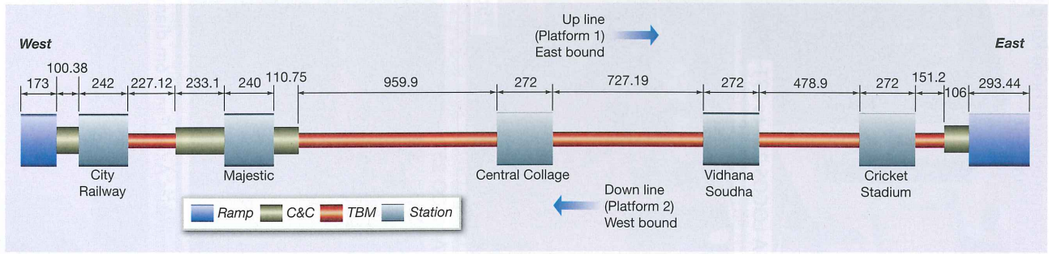
The short 227m drive from the pocket track cut to City Railway Station is yet another delicate stretch for the TBMs. The machines have to pass under some eight active railway lines operated by Indian Railways. It is expected to take a month to negotiate the route under the railway carefully monitoring any settlement using an array of monitors over the tracks.

Ramps and stations

The shallow alignment allows each of the stations to be excavated by cut and cover. Each station is 272m long with the exception of the far west 242m long City Railway Station which is restricted by rail lines on the east side and the ramp on the west side.

Soma's Shri R Richardson Asir explains that the stations are being excavated by drill and blast and constructed using either the top down or bottom up approach.

Below: Figure 4, the east-west alignment has more than 2.5km of twin bore tunnel



Getting the mud right

The TBM in Bangalore will encounter combinations of soft argillaceous material and harder rock at the same time. This is a classic problem in slurry tunnelling which increases the risk of over-mining (scouring) clays and silts during the enforced slower pace of advance imposed by the partial rock face.

One option in such circumstances is to simply reduce the slurry pump rate while negotiating hard ground. Conventionally, however, this variable is limited because ordinary bentonite and CMC muds require turbulent flow to keep cuttings in suspension.

A more viscous fluid - which is to say, a fluid with higher gel strength (gels) and yield point (YP) - can be formulated to have good conveying properties at a lower velocity range which will help avoid scouring.

Such fluids when comprised exclusively of CMC or bentonite would be too thick to pump. However, by analysing the underlying rheology - the nuts and bolts of how fluids behave - and providing the correct ingredients (in this case CMC plus MX Polymer), a suitable shear thinning fluid can be provided. The 'thixotropic' fluid used in Bangalore thickens at the face and in the lines, but is still easily pumpable, and its properties are monitored by CEC's tunnelling engineers using field viscometry and adjusted as required.

Ian Morrison, Mudtech

Soldier piles and rock dowels are used to support the excavation and the station is cast within the excavated pit.

Scientist and head of rock blasting and excavation at the National Institute of Rock Mechanics in India Dr H S Venkatesh says, "For the success of any blasting, especially in an urban environment, one needs to work on the weaknesses rather than the strengths." In this case the weaknesses are ground vibrations, air overpressure, control of flyrock and damage to adjacent rock mass. Venkatesh experimented with different blasting patterns, explosive types and volumes as well as cussions and barriers to develop an acceptable blasting method for the excavation. At some stations, buildings are in very close proximity to the blasting works so hoarding was needed to ensure no flyrock made it off the site. The details of the research to overcome these weaknesses will be the subject of a later paper.

The excavation of the east and west ramps that join the underground section to the elevated sections is being undertaken by CEC. Venkatesh says that, "Though blasting happens to be the safest, cheapest and fastest means of excavation, many-a-time urban situations may not permit blasting, and alternate means of excavation need to be adopted, which may be expensive and slow." CEC's Brown adds that for the east and west ramp blasting was ruled out because of urban restrictions. He explains there are tough restrictions on the number of blasts allowed each day, the size of the blast and the days you are allowed to blast. To increase the flexibility in the working pattern Brown has opted for the slower process of drill and split that uses hydraulic splitters in place of explosives to break up the rock.

At the far east end of the project, linking Cricket Stadium with the east ramp is a short 151m drive. Here there is silt and sandy silt on the tunnel alignment with some chance of weathered rock. A refurbished Robbins EPB machine was chosen for the drive. The alignment passes very close to the cricket stadium's lighting tower leaving the tunnellers having to tread carefully to avoid having to reposition the hundreds of bulbs that light the cricket pitch. Opting for the EPB machine makes it easier for the project to keep on schedule and is better able to tackle the soft ground.

Tunnelling work for the east-west line should be completed by the end of the summer next year.

香寶嘉 Dragages HongKong
A member of the Bouygues Construction group

西松建設 Nishimatsu Construction Co., Ltd.

SALE OF TUNNELLING EQUIPMENT

Design and Construction of Hong Kong West Drainage Tunnel
Contract No. DC/2007/10


SCHOMA LOCOS 25T to 27T


SCHOMA LOCO 25T


MAN BASKET CARS 500KG


HIAB CAR 5.6T @ 4.2m

25t LOCOS

11.5m³ Shuttle Car


Hagg Loader 2m³/Min, 8HR2-BH

FLAT – SEGEMENT CARS


SCHOMA LOCO 25T


LHD ST2D 1.7m³, Atlas Copco

11 & 12m³ Mixer Cars Muhlhauser


18 Seater Man Cars

Cogemacoustics Axial Fan 1.6m diameter
33.7m³/s


Various Axial Fans


UTRANAZZ TUNNEL MIXER 2m³, 1.5m (w)

6m³ Bottom Dump System Skips

0.5m³ with various attachments

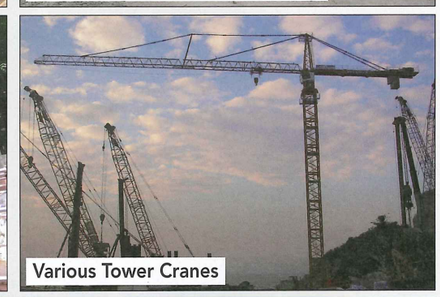
Various Excavators

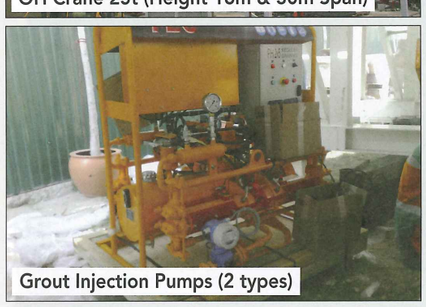

Volvo L70c, 1.8m³

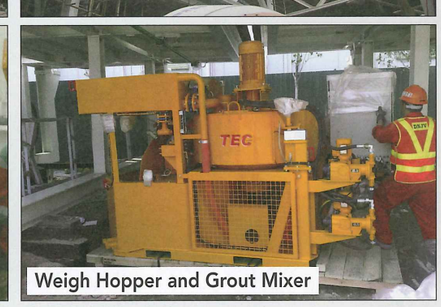

Under Carriage Cars for Skip 6m³

OH Crane 25t (Height 16m & 30m Span)

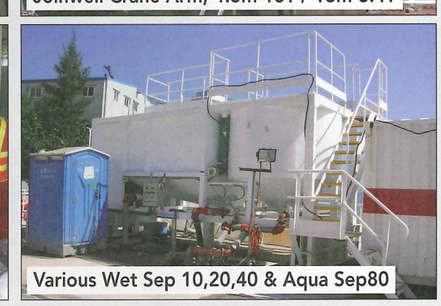

Joinwell Crane Arm, 4.5m-13T / 13m-3.4T


Various Tower Cranes


Grout Injection Pumps (2 types)



Weigh Hopper and Grout Mixer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RELEASE DATE
AUG 2011–MAR 2012

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Holding back to push forward

A TBM smashed by monsoons and a face so hard that at maximum thrust it was worn smooth as glass. Jon Young delves in to the challenges of delivering the longest tunnel without intermediate access in the world

The harshness of the terrain, the remoteness of the project and the violence of the weather are testing the skills and patience of tunnellers on the Alimineti Madhava Reddy (AMR) Project, India. The mammoth 43.5km tunnel is being driven at a 0.03 per cent gradient from both ends using identical TBMs.

But while fiercely hard and abrasive rock is wearing and slowing the outlet drive, a monsoon flood has wrecked the TBM on the inlet drive. As the team press on relentlessly Robbins project managers Martino Scialpi and Elisa Comis warn: "This is a marathon, not a sprint."

The tunnel will transfer floodwater from the Srisailam dam and reservoir on the Krishna River to arid regions of India's Andhra Pradesh state, providing irrigation to 1,200 km² of farmland and clean drinking water to 516 villages.

Contractor Jaiprakash Associates (JP) won the USD 413M engineer-procure-construct contract in 2005 from the Andhra Pradesh government to construct a head regulator and two tunnels, including the main 43.5km tunnel. On 26 May 2006, JP awarded a complete contract to Robbins for two 10m-diameter double shield TBMs, as well as conveyor systems, back-up systems, spare parts, personnel, and technical support.

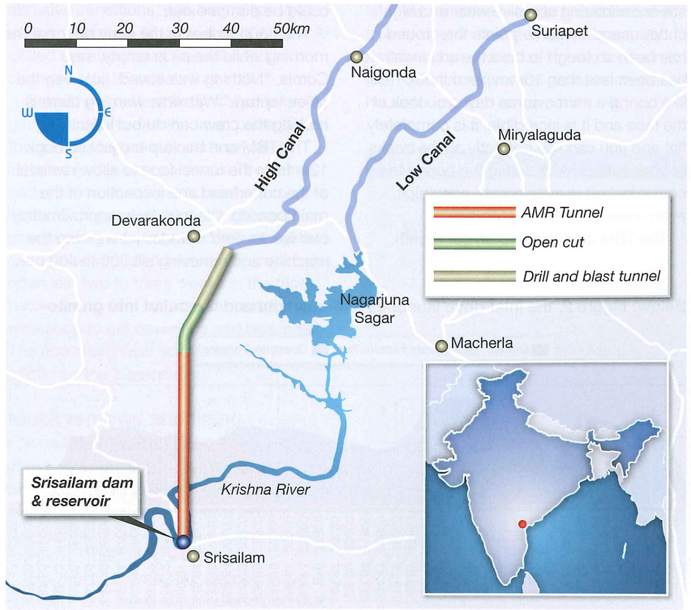
Outlet drive

When the TBM launched on the outlet drive in March 2008, Scialpi explains the crew was expecting to bore through hard granite with strengths of between 100 and 230MPa UCS. In reality he thinks the machine is facing strengths of up to 300MPa UCS. Scialpi says, "We measure this by comparing the thrust and the advance rate, we can see clearly that we are boring a rock harder than 230MPa."

To calculate the exact strength of the rock being bored, the team has begun taking samples to test the quartz content and the main features of the rock including the compressive strength and tensile stress. "These tests can give us a better understanding of the mechanical behaviour of the rock under our cutters," adds Comis.

Details of the geological conditions along the route are sketchy as there was only a limited amount of investigation work carried out. The tunnel's entire length passes under a tiger reserve, greatly restricting access.

The outlet drive launches into severely blocky ground, which tears the conveyor belt and slows the tunneling process. Large rock blocks make their way through the muck buckets, stopping in transfer hoppers and point loading the conveyor system. To counteract this problem, the spacing of grizzly bars on the muck buckets is reduced and additional bars are added so the boulders cannot pass onto the conveyor system. Grill bars are also added to the AMR inlet machine in anticipation of similar ground conditions. In good ground, the grill bars can be removed



Left: The outlet portal TBM launched into hard blocky ground;
Right: Figure 1, the AMR tunnel feeds the water canals for 516 villages

Above: A cutter disc unevenly worn after becoming stuck on the hard rock

to allow a higher flow of material into the muck hopper.

Scialpi says, "Where you find fractured rock you like to push as hard as you can but you have to restrain yourself as you risk delivering big blocks to the conveyor belt that could damage it. So you have to find a compromise between the real efficiency of the machine, which is able to obtain a penetration of 3m per hour, and the geological features you are boring."

By 2010, the outlet machine entered into better conditions with ideal stability, but is still encountering abrasive wear and high cutter usage. At some points the ground has been so tough to bore the advance rate has been less than 10mm per minute. "It is like boring a mirror, some days you look at the face and it is incredible, it is completely flat and you can see perfectly all the tracks of your cutters. And during the boring the conveyor belt is quite empty, just chips, even under your greatest thrust."

The TBM advances 300m per month.

Inlet drive

The Inlet machine is one week away from launch in October 2009 as a 100-year monsoon hits the region. Flood control doors are not opened in time to release the water downstream, causing the significant rise in water levels. The cofferdam wall at the inlet site is not designed to withstand a major flood, and is breached by the floodwaters. The launch pit is inundated with more than 20m of water, leaving the crown of the TBM beneath more than 10m of water for approximately 15 days until it could be pumped out.

The flood strikes in the early hours of the morning while the pit is empty, says Comis, "Nothing was saved, not even the office laptop." With little warning there is nothing the crew can do but watch.

The TBM and backup are jacked back 12m from the tunnel face to allow removal of the cutterhead and inspection of the main bearing. Cleanup lasts approximately two weeks, and includes jet washing the machine and removing silt 300 to 400 mm thick that is left on the machine.

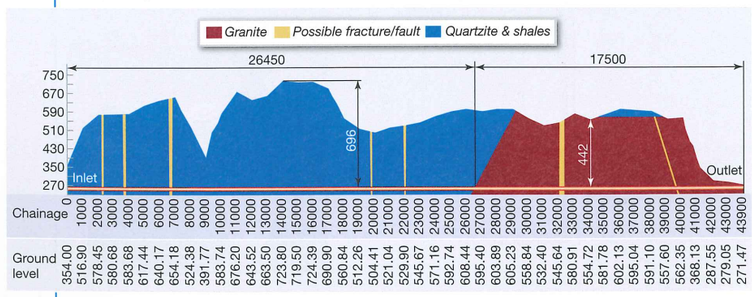
"The amount of damage was so high that they simply pumped out all of the water and started to do random checks on the equipment to get an idea of the extent of the damage. Most of the electrical equipment was completely destroyed and brand new replacements have been bought. A good 50 per cent of mechanical equipment has been repaired."

All the components are removed, assessed and repaired or replaced. The main bearing is so clogged with silt it is shipped back to the factory for checking. The insurance claim takes about a year to be agreed and in October 2010 rebuild work on the TBM picks up pace. The team are skilled in constructing the TBM on site as both the inlet and outlet machines were built on site using the Onsite First Time Assembly method, whereby the TBMs are not assembled first in a factory but instead the parts shipped directly to site.

The safety wall around the pit is raised 5m to prevent the same incident occurring again, it is now taller than the dam.

On 22 June the inlet TBM launches, boring the first 2m on the same day. The machine launches into quartzite, expected to be from 85 to 230MPa UCS for much of the drive but with possible spikes as high as 450MPa UCS. The quartzite is very abrasive; even more so than the granite on the outlet drive.

Below: Figure 2, the inlet drive launches into quartzite and the outlet into granite



Having twins

Finding the silver lining in the one and a half year delay to the inlet project, Scialpi says, "The flooded TBM will benefit from our experience gained on the outlet tunnel. We have learnt what to expect [under] these conditions, how the machine should sound and feel. All this experience will make for a smoother operation of the inlet project. The main points are the relationship between the TBM, the cutterhead and all the wear parts, the contact with the rock and the rock itself."

The inlet and the outlet drives are being driven by identical TBMs. The machines are 10m diameter Robbins double shields. A double shield is made of three shields, a large shield behind the cutterhead, a telescopic shield that moves in and out of the front shield as the TBM advances and a tail shield, which protects workers installing the lining. There is a two-storey backup on the machines with all the usual equipment.

Both machines have to undertake very long drives through hard abrasive rock. There is no intermediate access so all repairs and maintenance need to be carried out during the drive. To ensure the machine lasts the length all of it parts exposed to the rock have been given extra protection.

Comis explains, "The machines are especially made for hard rock. There is an additional skin all around the shield to cope with the wear over the very long drive. Extra wear plates also protect the cutterhead."

"Everything on the TBM was designed for very hard rock," says Sciapli "so the cutters are extremely heavy duty, the cutterhead is completely shielded with a hard facing, the cutter housing is especially made for this kind of rock but this is not yet enough. It is a long drive and with the rock we have to consider the real length."

With the long life of the project the machines need to be well maintained to ensure they can complete the drives. Cutters are checked every day and the cutterhead goes through a major overhaul every year to 15 months. The first overhaul on the outlet drive comes after 5.5km and sees an extensive refurbishment of the cutterhead, replacing all the wear plates. On 9 June the machine reaches the 10km mark and two weeks later is shut down for 10 weeks for its second overhaul.

Daily maintenance is carried out by the day shift. The machine is usually shut down for about four hours while disc cutters are inspected and replaced. The machines feature back-loading 20-inch diameter cutters for longer cutter life in the abrasive conditions, with twin discs in the centre. There are 67 cutters on the face. A skilled maintenance crew will need to change up to 25 cutters in a shift.

Brand new cutters are installed in the gauge positions and the used cutters from the gauge positions are removed and installed in the face positions. The same cutter will work several positions through its life. The gauge cutters are changed almost every day because the wear of the gauge position is so severe. The cutter can often last two to three weeks in the face before being sent back to the cutter workshop to get new rings and bearings. The maximum wear for the cutters is 35mm on the 20-inch disc.

Muck removal and lining

The restricted access to the tiger reserve above means that ground monitoring was ruled out. With no concerns about settlement, overbreak is measure by monitoring the advance rate against the amount of muck removed.

The muck is carried out on a continuous conveyor also being supplied and operated by Robbins. There is a drawback to using a continuous belt, especially in blocky conditions, if there is a crack or tear in the belt the whole system needs to be shut down and replaced. To counteract this issue the main contractor JP is installing intermediate chambers along the route, the first one at 12km. A new conveyor system will start from the chamber and feed muck from the machine to the first conveyor. Spacing chambers at 12km intervals limits the belt length to 24km. The chambers are being lined with wire mesh and shotcrete.

The tunnel is being finished with RCC precast bolted segments 300mm thick, 1.5m wide in a 6+1 arrangement. The segments are cast locally in a precast factory by the main contractor and trucked to site. There are no gaskets between the segment and the annular space is filled with pea gravel and grouted.

The tunnel will be under a small water pressure as the water level will be kept at a level slightly higher than the tunnel crown. The maximum pressure will be 3 bar.

Working in a remote part of India throws up some unusual challenges for the team. Towards the end of May the crew are carrying out routine cleaning of the telescopic shield when a viper snake is spotted on the TBM. The viper, which carries a lethal venom, had been brought to the TBM in empty sacks. Just a few weeks later the machine is home to another alien, a stray dog on the site has had puppies and one puppy decides to take the train to the TBM. It took several grown men several hours to trap and remove him.

Left: The continuous conveyor system carries muck from the TBM

TBM data

- Cutterhead nominal diameter: 10.0m
- Number of cutter discs: 67
- Cutter rings type: 20"
- Main bearing diameter: 6.7m
- Cutterhead electric motors: 12 x 315kW
- Number of main thrust cylinders: 12
- Stroke length: 1.6m
- Number of auxiliary thrust cylinders: 19
- Best day: 34.00m
- Best week: 148.80m
- Best month: 512.41
- Net penetration rate (average): 1.5m/h
- Cutters consumption (average): 1 cutter disc / 1.8m advancing

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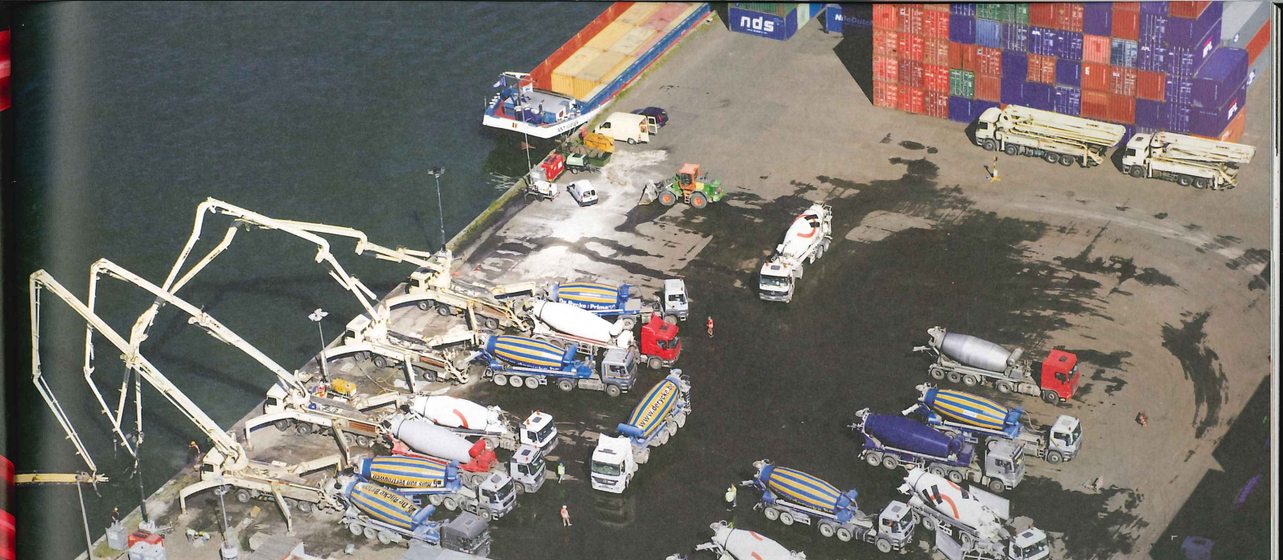


Speeding freight under Antwerp docks

In the highest value current construction project in Belgium an international public-private-partnership (PPP) consortium is building an important rail link to the west of Antwerp to handle the booming freight traffic to and from the port. The work includes tunnelling under waterways in tricky, soft-ground conditions and utilising an existing, but unused tunnel. Maurice Jones reports from Antwerp

One of two Herrenknecht Mixshield slurry TBMs, called 'Wiske', recently completed a 6km drive under the River Scheldt (River Escaut in French), and a dock waterway, for the 16.2km freight rail link between the two banks of the river to the west of Antwerp. The second, parallel, bore of the Liefkenshoek Tunnel will be completed by TBM 'Schanulleke' at the end of July. The TBM will break into the Kruisweg reception shaft on the 'Right Bank'. These bores will form Belgium's longest rail tunnels to date.

The various portions of the project are:

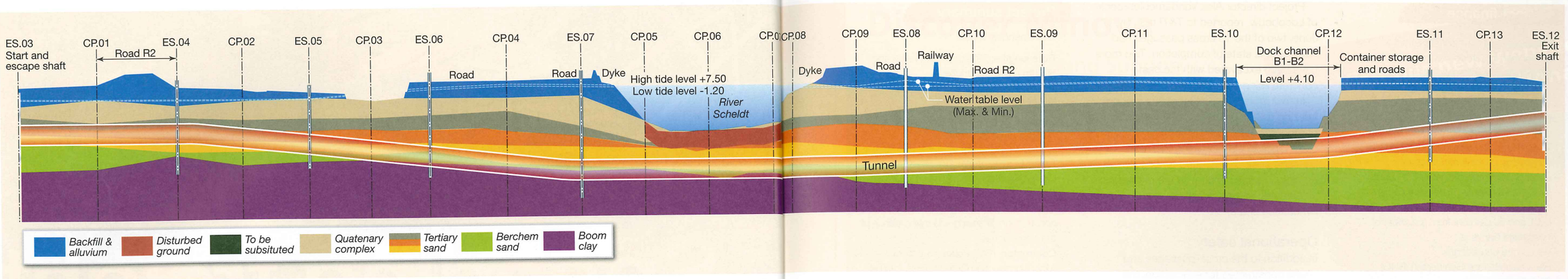
- Surface railway between Left Bank Rail Cluster South to existing Beveren rail tunnel
- Renovation and adaption of the cut-and-cover, twin-track Beveren Tunnel to modern requirements under Waslaandkanal
- Access tunnel between Beveren Tunnel and the new Liefkenshoek bores
- The twin Liefkenshoek Tunnel bores under the River Scheldt and the Dock Channel B1-B2
- Cut and cover and open cut ramp on Right Bank
- Adaptation of existing tunnel under R2 highway

The work is being carried out by the Locobouw consortium is a PPP scheme for Infrabel, the Belgian national rail transport agency. Participants in the scheme are Vinci, CFE and Bam.

Work is carried out 24h a day, seven days a week, to comply with the planned schedule. Around 530 people work on the project including the surface rail-route preparation, cut and cover (4.27km long) and open cut access ramps, and modifications to the existing 1.2km-long Beveren Tunnel.

Some 300 of these are craftsmen and labourers, 80 supervisors, and 150 working for sub-contractors. There is also another short (75m) tunnel to be adapted under highway R2 enabling the new rail link to meet with the marshalling yard at Antwerpen-Noord.

Below: Loading pre-cast segments onto a purpose-designed Metalliance trackless 'train' at the start shaft



Above: Figure 1, a section along the 6km-long Liefkenshoek bored tunnels

TBMs

The first Herrenknecht Mixshield to complete its drive (Wiske) was actually launched second, on 26 March 2010 from a shaft at Ploegweg.

The other, Schanulleke, was launched on 8 February 2010 and, as of 17 June, had just crossed under the dock channel, making good progress. Each TBM has a cutting diameter of 8.39m and cutterhead power of 1100kW.

The average TBM progress is about 15m a day, with simultaneous erection of precast concrete segmental lining in 1.8m wide rings totalling 6630 rings. Each ring consists of seven segments and a key. Delivery to the shaft site is by rail from a Max Bogl plant just across the German border. The rail route was specially extended for the project and has a planned capacity of 1200 segments per week.

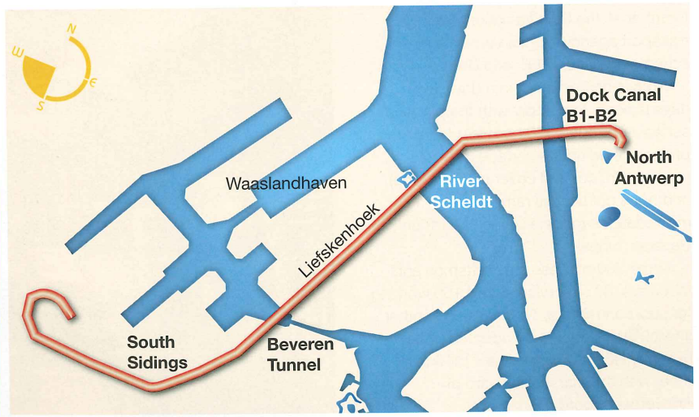
The maximum daily TBM progress achieved was 45m on 19 April this year. Progress of the first TBM was deliberately slowed compared to the second, to enable preparatory works for the cross passages to be carried out.

Each TBM utilises a computerised, laser-based guidance system manufactured and installed by CAP of France.

The bentonite slurry pressure is monitored in real-time; a control facility that is particularly important under waterways (see below).

The slurry density is controlled from the spoil separation and treatment plant designed and manufactured by MS of France to handle the very fine sand and silt, which can be troublesome. These are separated from the water medium with the aid of filter presses.

Right: Arrival of TBM 'Bobette' or 'Wiske' to complete the first bore of Liefkenshoek; Below: Figure 2, A map of the complete 16.2km Liefkenshoek rail route through Antwerp's western docks;



Ground conditions

The ground on the tunnel alignment comprises mainly waterlogged loose sand although clay may be encountered in the low part of the face in the middle section of the drives partially under the River Scheldt. These conditions present no problem for the Mixshield TBMs except for the passages under the Scheldt itself and the Kanaaldock (Dock Channel, see below). Fortunately the clay is excavated as lumps and does not become too sticky nor break down into the slurry medium.

Where intervention is required to change cutters and carry out other maintenance, previous experience has shown that these can be very difficult in the high groundwater pressures experienced in the region, even with the possibility of creating

Right: Excavating a cross-passage in frozen ground; Right, bottom: Installing cross-passage concrete reinforcement cage within a waterproofing membrane layer

a face slurry-cake seal and using compressed air. Project director Alex Vandemeulebroecke explains that the maximum pressure expected on the TBM face is four bar, which is the maximum allowed under Belgian health and safety law so leaving no margin for error. Therefore it was decided to use planned 'maintenance boxes' in the tunnel drives consisting of cement/bentonite blocks constructed from the surface. It is then possible to carry out other maintenance work at atmospheric pressure.

Under waterways

Crucial phases of the project have been the TBMs crossings under the River Scheldt and also the channel to dock B1-B2 without any disruption to shipping. The cover under the Scheldt is only about 10m (40m below water level), and 30m below water level under the dock canal (see figure 2, above). It was decided to place a concrete mat on the bed of the Dock Canal for final cover of 3.5m including the mat. This will not only provide additional protection for the completed tunnels, but also help to prevent pressurised slurry blow-outs when the TBM passes below, with low cover, using the weight of the concrete and diverting the weakest path for pressure loss.

The TBM slurry density and pressures are carefully controlled to prevent such an occurrence. This is aided by a real-time pressure measuring system. In the soft ground and less cover below the waterways, however, these additional precautions were deemed necessary. Tidal effects also have to be taken into consideration as the variations can create up to 0.6 bar extra pressure on the TBM face at Spring high tides.

Dredging International, a CFE subsidiary, dredged silts from the canal beween two previously installed walls of sheet piling. The contractor then placed 25000m³ of slow-setting mass concrete in the dock channel in May last year over a four-day continuous period.

This was accomplished using pontoon barges and divers in a tremieing operation away from the bank, and also using four truck-mounted concrete pumps from the bank being fed from four batching plants using 120 truck mixers. Some 240 people were involved in the operation including several divers.

In July, 17,000m³ more of concrete, but this time a rapid-setting mix with steel fibres, was poured in the same way to create two, 2m-thick concrete slabs on top. These act as a counterweight during TBM passage, as previously described, and also act as protection against impact by ship anchors. As can be seen on the section the TBMs bored through the placed mortar as well as the Tertiary sands.

Cross-passages and escape

The second drive allows for the construction of a number of ancillary works including evacuation shafts, cross passages between the bores, and a platform/walkway to facilitate maintenance and the passage of work trains. This ancillary excavation work includes shafts at every 600m for evacuation and 13 cross-passages spaced at every 300m along the tunnel. Each shaft, excavated within diaphragm walls, measures 21 x 6m in plan, and with depths ranging from 28 to 45m. In order to keep out groundwater when connecting with the tunnel bores seven of the shafts use cement bentonite slurry in diaphragm walls installed by Soletanche Bachy, and the other one has been excavated through frozen ground as linked with the cross passages.

Soletanche Bachy, together with Belgian subsidiary Fontec, was also sub-contracted for other retaining walls in cut and cover stretches. In total there are 145,000m² of diaphragm walls and 95,000m² of cement-bentonite cut-off walls. These range in

Project finance

The project was named 'Infrastructure Deal of the Year' in Europe in January 2009 by Project Finance International PFI magazine, in recognition of the original way it has been financed. As the project concessionist, Infrabel arranged finance to the total of approximately EUR 765M (USD 1084M). The construction is being financed in a PPP scheme by Locorail with a capital expenditure of approximately EUR 690M (USD 978M). Some 50 per cent of this comes from the European Investment Bank (EIB), and 50 per cent from a number of investment banks as:
Bayerische Landesbank
Bank Nederlandse Gemeenten (BNG)
BNP Paribas Fortis
ING
Banco Santander
Societe Generale

Additional project finance comes from the Flemish Region (EUR 107M – USD 155M) and Infrabel itself (EUR 75M – USD 109M) outside of the Design-Build-Finance-Maintain order, intended for rail equipment installation.

Locorail is composed of:
CFE (25 per cent)
Vinci Concessions SA (25 per cent)
BAM PPP Investments Belgium (50 per cent)

THV Locobouw is contracted to Locorail for construction work, and has the composition:
Vinci Construction Grands Projets (25 per cent)
MBG (CFE group) (25 Per cent)
CEI-De Meyer (BAM group) (25 per cent)
Wayss & Freytag (BAM group) (25 per cent)

The PPP revenue and maintenance period is 42 years including 38 years of maintenance. Revenue will be in the form of quarterly fee based on tunnel availability and will amount to about EUR50M (USD 71M) a year. In order to keep the port competitive and facilitate container transport, there will be no fees to use the rail link.

depth from 15 to 40m and are generally constructed to penetrate the impermeable clay beneath the rail route. Three trench excavators have been used on a five-day week around the clock.

As has been the case with other crossings under the Scheldt, the soft, waterlogged ground makes the use of carefully controlled ground-freezing procedures necessary. All excavation and lining is carried out in frozen ground and then the ground-freeze connection is shut off for controlled defrosting.

Project director Alex Vandemeulebroecke of Locobouw reported to *T&TI* that, by 17 June, two of the 13 cross passages had reached this state of completion. Two more have been excavated with the cast concrete lining being installed.

In four more passage locations ground freezing has commenced. The installation of ground-freeze pipes is soon to commence in the remaining five cross-passage positions. Ground freezing employs a brine circuit with the refrigeration unit located in the start shaft or an evacuation shaft.

Operational safety

In addition to the cross-passages and shafts constructed for evacuation, the tunnel design includes a number of other safety features.

The concrete used in construction of the Liefkenshoek Tunnel and renovation of the Beveren Tunnel is fire-resistant by virtue of using a fire-resistant sprayed concrete mix including vermiculite expanding mineral to provide insulation to 380°C. The steel reinforcement bar starts to be heated at 250°C. The pre-cast concrete segments include polypropylene fibres to prevent spalling in a fire. In both cases the lining has been tested according to the RWS curve criteria without destroying the lining.

A fire detection system, to include CCTV imaging, will be installed, together with ventilation to remove any smoke and excess heat. There will also be an automatic 'hot foam' extinguishing system, used for the first time in a rail tunnel, and designed by a joint venture (Locofire) of the BAM group and a local specialist fire engineering company AquaSecurity. Similar systems have been used extensively in chemical industry infrastructure.

Stevens, a subsidiary of CFE, is installing electrical cabling.

Environment

The project pays careful attention to environmental protection. In tunnelling terms this includes the MS slurry recycling plant for spoil separation from the bentonite slurry and controlling water discharge. Where the 6.5km of surface route is disturbing part of a wetlands nature reserve with protected species of frogs and birds, this is has been compensated by a new 54-hectare (133-acre) site at the The Groot Rietveld old farming area in Kallo. Sound absorbent screens have been erected at strategic locations.

As much as possible of the tunnel spoil, and other excavated material, will be used as trackbed fill, material to build noise barriers and dykes, or built into slopes near the track and planted with trees. Locobouw will be responsible for the upkeep of such environmental measures for two years.

Project summary

Liefkenshoek Tunnel

Bore lengths: 5972m (TBM Wiske) and 5979m (TBM Schanulleke)
Tunnel lengths (inc. cut-and-cover shafts): 6745m and 6752m
Bore outer diameter: 8.10m
Tunnels inner diameter: 7.30m

Project participants:
Concessionist: Infrabel
Client: Locorail consortium (see Project Finance panel; in charge of design, construction, financing and maintenance of the infrastructure)
Contractor: THV Locobouw consortium (Vinci Construction Grand Projets - 25 per cent, CFE group (47 per cent owned by Vinci) – 25 per cent, BAM Wayss u Freytag – 25 per cent, BAM CEI de Meyer – 25 per cent), led by MBG of CFE Group
Tunnelling supervision & design services: TUC Rail (Infrabel rail technology consultant)

Schedule:
Civil engineering construction: 12 November 2008-mid-2013
Railway equipment installation: 2012-Spring 2014 for commissioning
Availability to railway operators: Mid-2014

Conclusion

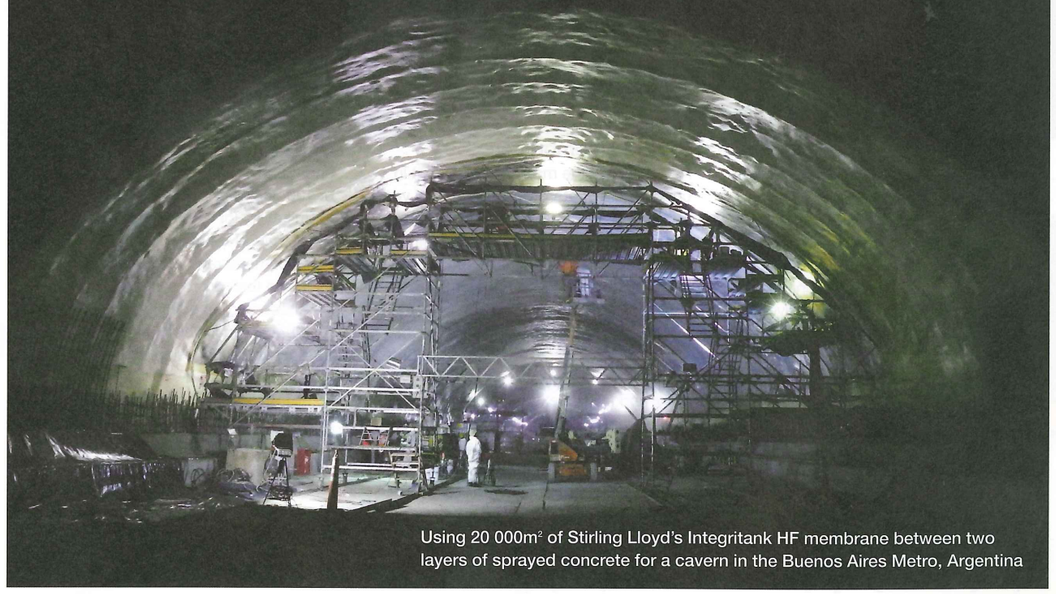
All civil engineering works by THV Locobouw are due for completion mid-2013 following commencement in November 2008. The new rail link is scheduled for completion mid-2014, providing a large increase in rail freight capacity to serve the port of Antwerp in linking Waaslanhaven and Antwerpen-Noord direct. Trains will no longer have to make a detour around the junctions at the Kennedy rail tunnel and the rail axis Antwerpen-Berchem to Schijnpoort. It will also free up capacity for more passenger traffic on these routes. Infrabel would like to expand the share of rail traffic in the port to 15 per cent by 2020.

Acknowledgement

T&TI is grateful to Clarence Michel of Vinci Construction Grands Projets for arranging the project visit and briefing material, and to Alex Vandemeulebroecke, Lionel Suquet and Locobouw staff for conducting the visit.

Membranes in the mix

There are many approaches to trying to keep a tunnel permanently dry, and as many factors in whether a method is a success. Maurice Jones enters the battle between competing membrane systems



Using 20 000m² of Stirling Lloyd's Integritank HF membrane between two layers of sprayed concrete for a cavern in the Buenos Aires Metro, Argentina

It is difficult for any new method to break into the tunnelling market unless there is the potential for major costs savings. Natural conservatives say 'why take the risk?' if there is no obvious benefit, especially when design lifetimes are around 100 years. Even if there is cost-saving potential, the method has to prove itself to all specifiers and customers on matters such as ease of installation, efficacy for the purpose, durability and safety. This is where performance criteria become important rather than demanding physical properties that should also be proven and may become outdated.

The introduction of spray-on water-barrier membranes has, so far, mirrored the acceptance of sprayed concrete in that the attraction of potential cost-savings and apparent ease of application has been persuasive in many cases. Such is the similarity in approach that several suppliers and contractors are promoting a 'sandwich approach' to sprayed tunnel linings in which the water-barrier membrane is bonded within two or more layers of sprayed concrete.

There are a number of methods of water control that maybe employed:

- Dewatering – mainly pumping from groundwater
- Pregrouting – sealing ground fissures and pores before excavation
- Remedial grouting – as above but during construction if ther is water ingress
- Tanking – principally for cut and cover and immersed tube tunnels with sheet materials and liquid applied membranes
- Gaskets – essential for pre-cast segmental lining and cast-in waterstops
- Sheet membranes – see below
- Sprayed membranes – see below

Above: Soprema sheet waterproofing membrane used in cut-and-cover tunnelling for Line C of the Rome Metro

- Waterproof concrete – produced by the use of special concrete mixes with additives to deter shrinkage and minimise porosity
- Crystallisation – the use of crystal-forming penetrative solutions to block pores in concrete
- Plugging – including remedial grouting.

Sheet membranes

Construction materials specialists and plastics manufacturers supply sheet membranes, usually PVC, that are installed underground as part of the designed lining and prevent water ingress and/or divert it to drains. Some supplied for roofing or water reservoirs may not be suitable for the generally more demanding conditions of the underground environment. In addition there are thicker dimpled plastic sheets, such as those manufactured by Dorken, placed beneath the permanent structural lining and tunnel invert to facilitate water drainage.

Sheet membrane lining has long been criticised in some quarters due mainly to the potential for damage causing leaks that can be difficult to trace to source. The labour-intensive and sometimes complex nature of installation has also been a drawback to some, but often with few alternatives. The advent of sprayed membranes has put sheet membrane suppliers in a much more competitive situation, but one from which they are starting to fight back.

On the question of possible damage Flag-Soprema produces a coextruded PVC membrane with the two surfaces in different colours. This means that any accidental holes in the material that may occur to the upper, light green surface during installation become immediately visible as the black colour of the lower layer shows through. Welding over a patch can repair any such damage.

Flag-Soprema's Sarah Langley points out that its sheet membranes are of guaranteed thickness whereas the thickness of sprayed membranes depends on the operator's efficiency and constant testing.

Recent Soprema sheet membrane installations include Bulgaria's Sofia Metro Line Two, Rome Metro Line B1 and Line C and the new Tyne Tunnel.

Sika's Sikaplan PVC and FPO tunnel membranes have been installed in the Gotthard Base Tunnel in conjunction with sprayed concrete lining. The lining system was subjected to pre-qualification testing in Switzerland's Hagerbach testing gallery.

All successful sheet-membrane waterproofing installations depend on secure overlap joints between sheets carried out with welding or adhesives. These joints can be pressure tested afterwards. Some manufacturers offer Velcro fastening at sheet edges to aid joint assembly.

Sprayed membranes

As potentially the major development in underground waterproofing for many years, sprayed membranes form a rapidly increasing market sector, and are in competition with the established market for sheet membranes. The attraction of a waterproofing method that can be applied over asymmetrical or rough surfaces at a reduced labour cost is seductive, but the full story shows that it is not always that easy, and a lot of expertise has to be included in the process. Many suppliers now point out that the surface should be made fairly smooth, with a layer of fine concrete, before the sprayed membrane is applied.

Various established construction chemical and waterproofing specialists have, during the last decade, taken initial steps into the tunnelling market with liquid-applied membranes including BASF Meyco, Sika, Stirling Lloyd and Tam Normet. First projects have been completed, usually successfully, and more trials are under way to convince specifiers of the merits of application and durability. The basics have been well established in surface applications including immersed tube and cut and cover tunnels, nuclear containment, water services tanks and bridges. Application underground is more of a challenge in which clients and their engineers have taken an understandably cautious approach, as they had done with sheet membranes.

But sprayed lining suppliers, such as Stirling Lloyd, which offers the Integritank HF spray systems, as well as brush and spray-applied materials for open-air applications, do not claim that such membranes are a panacea for all waterproofing scenarios in any case. Indeed, sometimes both sheet and sprayed membranes have been used on different parts of the same project, depending on suitability for site conditions.

Bonding between sessions of sprayed lining can often be a problem but Stirling Lloyd's development director, Mike Harper says not in their case. "The chemistry of the resins used in Integritank HF ensure that it will form a strong bond to itself irrespective of the time between applications," he says. "The whole ethos of the system is based on this ability. The first coat is left to fully cure before the application of the second coat, so a true two coat system is provided."

"At day joints [shift breaks] we ensure a totally seamless system by overlapping onto the existing material rather than butting up to it. These laps have been independently tested by The Technology Centre owned by Vinci Construction UK and found to be resistant to water pressure of 100 bar, when the test was concluded."

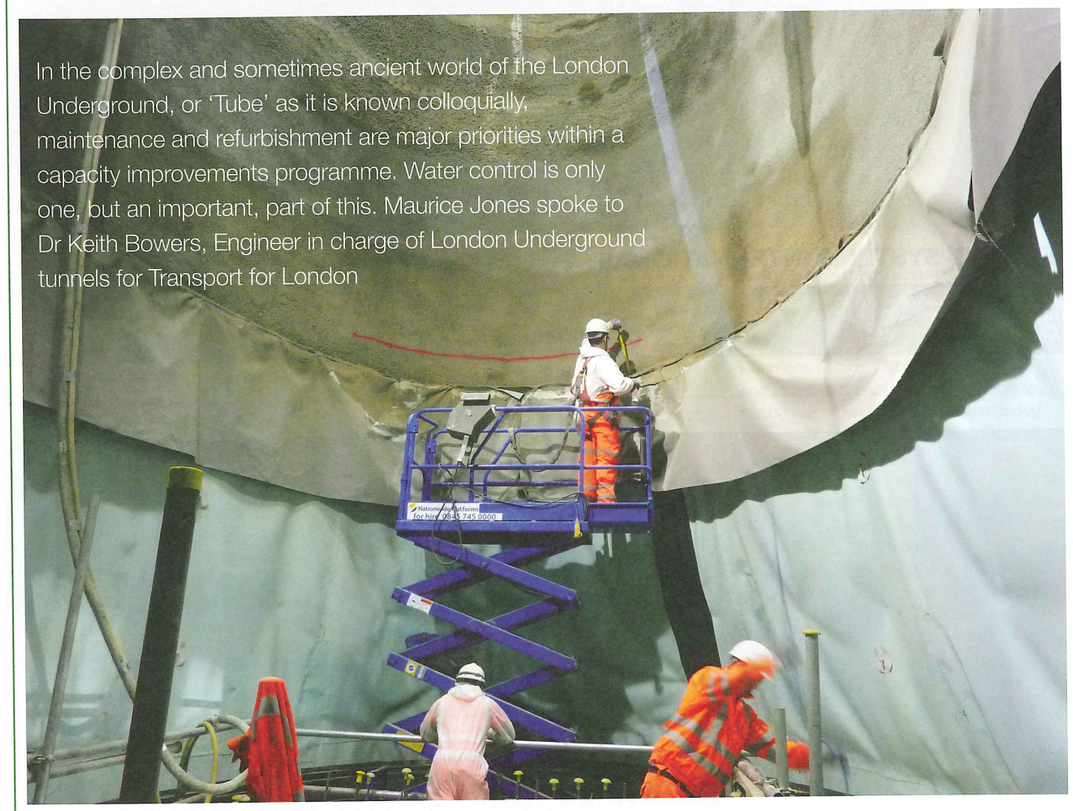
Suitability for long-term durability and maintenance are major issues for both types of membrane, which programmes of trials and testing are being used to prove. Another common point is that both forms of membrane require skilled applicators with qualification supervision and quality assurance to ensure an effective installation. In the case of Stirling Lloyd's Integritank HF the membrane's integrity can be electronically tested in situ after installation, revealing even a pinhole defect.

Sandwiching

An extended development in the use of sprayed membranes is their use within a 'sandwich' such as in the case of Lasershell developed by Morgan Sindall and Bemo of Austria, and used on tunnels at London's Kings Cross Station and London Heathrow Airport Terminal 5 (in joint venture with Vinci Construction Grands Projets) BASF Meyco is also now emphasising this means of using spray-applied membrane, and it is also offered by Stirling Lloyd for encapsulation on the primary sprayed concrete lining by the secondary (internal) lining, regardless of whether it is another layer of sprayed concrete or cast in situ. Recent installations of the company's Integritank HF membrane include 20 000m² to waterproof a sprayed concrete lined cavern in the Buenos Aires metro.

Keeping London Underground dry

In the complex and sometimes ancient world of the London Underground, or 'Tube' as it is known colloquially, maintenance and refurbishment are major priorities within a capacity improvements programme. Water control is only one, but an important, part of this. Maurice Jones spoke to Dr Keith Bowers, Engineer in charge of London Underground tunnels for Transport for London



The London Underground metro network's history started with the world's first underground metropolitan railway (hence 'metro') in 1863, many of the tunnels of which are still being used. It follows that there has to be a heavy programme of maintenance and development, including protection against water.

"Waterproofing technology is currently evolving," says Dr Keith Bowers, "and is driven mainly by new build, with the situation on maintenance requirements fairly steady."

Some of the refurbishment work on London Underground has been associated with links to new works for Crossrail, a programme to help cope with an urgent need for increased capacity.

Last year was the busiest ever on London Underground with 1.1bn journeys, a 10 per cent increase on 2009.

The need to increase capacity is likely to continue into the foreseeable future, as extra capacity seems to be absorbed quickly. A major aspect of the programme to increase capacity is to create a more efficient flow of people to and from the trains, including the new Northern Ticket Hall at Victoria; currently the busiest station.

London Underground has its own standards covering the level of water control required. These require waterproofing to ensure the absence or removal of any water drips above passenger access ways in existing tunnels and over track and electrical equipment. Lower down in the running tunnels the requirements are more tolerant and permit the diversion or 'tanking' of water so that it does not cause a nuisance and can be drained away. In new works the aspiration is to create an 'entirely dry' tunnel, says Bowers.

"LU is currently updating its tunnelling and waterproofing standards and plans to issue revised versions of all of them by the end of 2011. The latest London Underground technical specification [see Tech spec, right] is T0006 covering materials and workmanship in deep tube tunnels. London Underground standards focus on 'performance requirements'. In other words, will the system do what we want of it? Nonetheless, the standards, specification and guidance notes all provide information on specific approaches that have been found to work well in the railway environment."

Membrane pros and cons

In comparing sheet and sprayed or 'liquid-applied' membranes for refurbishment Bowers says, "Both systems have pros and cons. Sheets are quite efficient large, simple shapes such as highway tunnel linings. They only tend to leak if abused, by a puncture for example." Sheets can be awkward to install where tunnels are geometrically complicated such as in station passageways.

Also with sheet membranes, voids on both sides of the membrane mean that the one behind can fill with water. If the water leaks out somewhere, the ingress point may be nowhere near the external source of the water, so it can be difficult to rectify. Sprayed membranes can bond to the linings without leaving hidden water paths thus making repairs easier."

"On the other hand,' he continues, "sprayed systems are not much use when applied to running water. In such cases the water has to be diverted first using sheets or stainless-steel channels."

He adds, "A further complication is that currently available sprayed products can have very different characteristics. There are possible solvent problems, for instance, meaning some may pose health risks if used underground in confined spaces or near connections to areas of public access. Membrane performance in case of fire must also be considered."

Other approaches

"Another way to improve water-tightness," says Bowers, "is to use high quality concrete in linings, with appropriate additives in the mix as necessary. However, the main problems with water paths are usually at the lining joints, so relying on the concrete alone is not acceptable."

Bowers says that, whatever the waterproofing system, London Underground favours 'reinjectable' grout pipes at high risk areas such as tunnel junctions so that any leaks can be rectified more easily later in the structure's life.

Green Park

One example of an ongoing refurbishment on London Underground is the step-free access project at Green Park station, where the contractors and consultants Joseph Gallagher, TubeLines and Capita Symonds used both sheet and sprayed-on membranes. BASF's Masterseal sprayed on waterproofing membrane was used at the top of the new passenger access shaft, and sheet membranes in lower sections.

The project was the subject of a BTS meeting in March and will be reported in *T&TI* in the near future.

Membrane application

Isolated compartments behind the sheet membrane have to be created by welding water bars to it with the full encirclement of tunnels and shafts. The compartment must be no longer than 10m.

There is a special requirement for the interface between superficial geological deposits and the London Clay where the barrier must consist of at least three separate water bars.

Before applying sprayed waterproofing membrane, the surface (assuming sprayed concrete) has to be cleaned of surface contamination such as dust oil and loose particles. The surface has to be smooth enough to permit an even, continuous spray of the membrane.

If the surface is too rough for full or economical coverage, a regulating layer of sprayed concrete has to be used with aggregate not greater than 4mm. If an application of sprayed membrane is defective the section has to be resprayed with a minimum overlap of 200mm over the boundaries of the defect.

The sprayed membrane has to bond well with the primary lining to prevent movement of groundwater behind it. This bond must be better than 0.5MPa strength, tested to the relevant British Standard.

Also water movement between the membrane and the secondary lining has to be restricted so that any necessary leak sealing treatment can be effective. In a similar way to sheet membranes, compartmentalisation of lining may be used to prevent water migration longitudinally.

Tech spec

The recently issued London Underground technical specification T0006, 'Deep Tube Tunnels – Materials & Workmanship' covers the materials and workmanship to be used in deep (bored) tunnels and shafts of the London Underground network, as distinct from the shallow underground (chiefly cut and cover) routes. Its scope includes sprayed concrete, segments and 'squarework' and other structures linked to deep tunnels. Much of the specification is based on the BTS 'Specification for Tunnelling' Third Edition.

The clause referring to sheet membranes for waterproofing is as for the BTS publication. With reference to Bowers comments regarding the composition of the sprayed material, the clause dealing with such membranes has been rewritten as:

'To comply with the general requirements of COSHH Regulation 7(2) to avoid the use of materials hazardous to health in the workplace no part of any component of the systems shall contain either substances classified as Category One, Two or Three carcinogens, mutagens or teratogens (substances toxic to reproduction) or substances classified as respiratory or skin sensitisers (potential occupational allergens) in accordance with Regulation Four of the Chemicals (Hazard Information and Packaging for supply) (CHIP) Regulations 2009. Without prejudice to the above prohibitions, there exists a further requirement to use materials not classified as hazardous according to the CHIP Regulations so far as is reasonably practicable."

Acceptance of a waterproof membrane's performance is subject to London Underground Tunnel Standard 1-055.

As mentioned in the main article, materials have to comply with London Underground Category One Standard 1-085 'Fire Safety Performance of Materials' in respect of flammability, smoke emission and toxic fume emission in sub-surface applications, unless a concession or fire waver is granted. This is of particular attention in reference to hydrocarbon-based materials and applies to gaskets as well as other water control materials.

As regards water control during construction, the specification places a duty on a contractor spraying concrete lining to control groundwater flow, including channelling by pipes or chasing. The channels have to be plugged on completion of spraying to prevent further water ingress.

References

National Archives UK Statute Law Database. (The) Chemicals (Hazard Information and Packaging for Supply) (CHIP4) Regulations 2009 (SI 2009/716)

National Archives UK Statute Law Database. Control of Substances Hazardous to Health Regulations (COSHH) 2002 (SI 2002/2677); amended by SI 2003/978 & SI 3004/3386.

Transport for London - London Underground. Deep Tube Tunnels – Materials and Workmanship, Technical Specification T0006, issue no. A1. March 2011 by Mayor of London

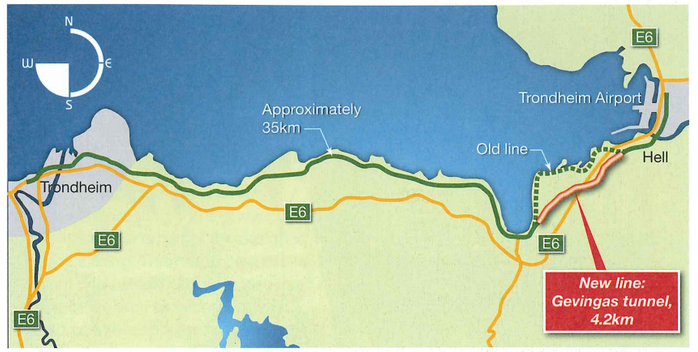
Norwegian railways protect assets from freezing

A new rail tunnel on the Norwegian coast is the first in the world to have sprayed waterproofing membrane tested for reliability in freezing conditions. In co-operation with the nearby facilities of Sintef in Trondheim, a major programme to confirm lifetime expectations has been under way, Maurice Jones reports from site

'Reliability', or at least the Norwegian equivalent, is a big buzzword amongst infrastructure engineers at present. The matter was brought to a head following widespread public criticism of Jernbaneverket (the Norwegian rail infrastructure authority) and NBS Norwegian railways caused by weather-induced service stoppages during 2010.

As a long-time leader in the annual length of tunnelling, Norway has many tunnels of fairly basic design, excavated by drill and blast through competent rock, with simple or no support lining. With the large investment in infrastructure made possible by North Sea oil revenues, particularly to link far-flung settlements and shorten travel times in fjord districts, tunnel design has become more sophisticated.

A major aspect of this increasingly sophisticated design approach is to improve water control. Whereas leaks could formerly be tolerated in tunnels with low traffic, frozen water leading to icicles can be dangerous. With higher levels and speeds of traffic, both in rail and road tunnels, such conditions cannot be tolerated. Safety measures in general also have to be brought up to modern expectations,



Left: Hell freezing over? The north Hell portal, junction with the existing railway and its narrow coastal route; Above: Figure 1, map of the new tunnel location between Trondheim and the airport

including escape routes and ventilation.

With the greatly increased tunnelled infrastructure network, including its upgraded facilities, there is a concern that the relatively small population of Norway cannot afford to maintain such assets, perhaps when energy revenues reduce. Therefore it is essential that all new and refurbished tunnels have to be constructed to a standard that will ensure reliability and long periods between maintenance.

Tunnel to Hell

To the north of Trondheim, about half-way along the long western coast of Norway, Jernbaneverket decided to construct a tunnel, the Gevingasen Tunnel, away from the coast, to improve the reliability of the Nordland service. In the past, landslips and snowfall have closed the route in the winter, on the narrow coastal strip of land where the route now runs. The new tunnel will allow this route to be closed.

There has been some public controversy about whether the tunnel should have been for double-track and designed for high-speed trains, defined in Norway as up to 250km/h. However, while the tunnel allows for electrification, the layout of the rail connections at each end of the tunnel will not allow trains above 160km/h for the foreseeable future. Current traffic plans are for one passenger train per hour, but with a fairly high level of freight use such as two-three trains per day in each direction. The tunnel has increased total route capacity to eight trains an hour serving Stjordal.

The tunnel is 4.4km long between Hommelvik and Hell, near Stjordal and Trondheim's Vaernes airport. As it happens, the new tunnel's north portal is near the village of Hell, on roughly the same route as the E6 'Helltunnel' for the main south-north highway, and so is the cause of much amusement for visitors, but its name is hardly reflected by the temperatures.

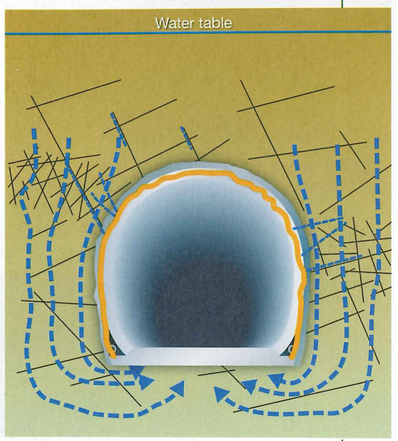
The tunnel has been excavated in metasediments consisting mainly of sandstones and siltstone shales partially metamorphosed. The low presence of minerals that can be dissolved or carried away by water means that a drainage method of water control can be carried out as described below.

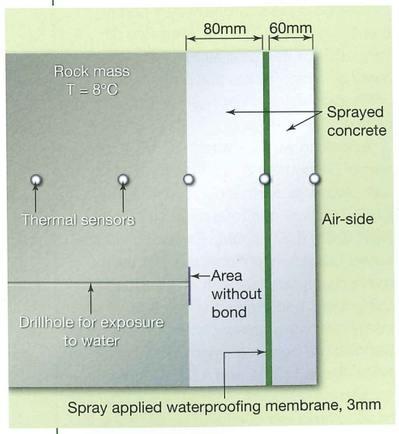
Tunnelling was contracted to Mika, now part of Betonmast Bygg, in 2009. The tunnel work is worth around NOK 400M (USD 74M) out of a total project costs of NOK 650M (USD 120M). Excavation of the tunnel using conventional drill and blast methods is complete with only support lining, track bed laying and services installation in progress. Three twin-boom Sandvik drill rigs were used (models DT 1120, Axera T11/12 and a DT 920). The section is horseshoe-shape 6.4 x 6.5m high to accommodate overhead power lines. In addition to the running tunnel, other excavations include access ways and escape routes, two of three of which link with the E6 Helltunnel.

There is also a possible interaction with the small-section Finatunnel that has to be allowed for in the excavation and support design. The Gevingasen Tunnel passes below the bore that carries aviation fuel lines to the nearby airport.

In addition to the installation of frost-resistant waterproofing, further cold weather precautions include the use of Sundec hard foam boards within the rail track bed. Jernbanverket construction manager Christoffer Ostvik explains that these boards are designed to protect the

Below left: Prof Eivind Grov with hydraulic connections to the test apparatus and granite blocks at Sintef Below right: Figure 2, section through Gevingasen Tunnel to show drainage design and position of membrane





Above: Figure 3, diagrammatic section through the Sintef tunnel wall test with cold 'tunnel' on the right Above right: Jerbaneverket project manager Christoffer Ostvik (right) with Mika contract site manager Ove Rabba at the northern Hell portal

bed against frost and likely consequent structural deterioration, in line with the recent emphasis on service reliability.

The tunnel is due for handover to Jerbanverket later this year after approximately 2.5 years of work.

Waterproofing

Masterseal 245 was first trialled in a small tunnel in Norway in 2008, but the Gavingasen Tunnel is the first full-scale installation in a Nordic country. Following its application to a short section in 2009 and Sintef tests (see below) Jernbaneverket agreed to apply the new system to a length of approximately 1850m in the central part of the tunnel along with more conventional methods of sealed draining at either end.

Left: An AMV 7450 access and concrete spraying unit is used to aid application of the Masteral 245 waterproof membrane

BASF's Karl-Gunnar Holter explains that as the main design for the tunnel had already been made, the inclusion of Masterseal together with sprayed concrete lining could be brought forward quickly, with initiation of work within six months.

The ground surrounding the Gevingasen Tunnel was only partially pre-injected with grout to consolidate the portal area, prevent settlement and to protect the aquifers serving the needs of some residences above the tunnel route. Consequently, although this had some effect on tunnel waterproofing, it was not the main purpose of grouting. Specialist waterproofing was still necessary. The expected groundwater pressure head on the lining is 0.6 bar at the tunnel crown and 0.8 bar at the walls, being much less than the designed 5-bar limit of the sprayed concrete and 3mm-thick Masterseal 345 lining. It is expected, therefore, that any groundwater approaching the finished tunnel will be diverted through to the tunnel invert and channelled to a main pumping station.

Masterseal was applied using conventional sprayed concrete equipment, with the applied thickness of 3mm being verified during application. Firstly the roughness of the first layer of sprayed concrete, including polypropylene reinforcement fibres, was measured to ascertain its suitability for Masterseal. Although Masterseal can be applied directly onto fibres it was decided to apply a smoothing layer first.

Once the Masterseal had been sprayed to a thickness of 3mm it was left to cure before applying the internal, bonded layer of sprayed concrete. As the work was carried out in the cold temperatures between mid-November and the end of March last winter, this took about a week to achieve the necessary hardness of Shore 50 before applying the sprayed concrete.

Within this 'sandwich' concept of sprayed concrete lining and bonded internal waterproofing, the first layer of sprayed concrete is part of the designed permanent lining. This has to be a minimum of 80mm thick. Rockbolts were also used in support of the arch as necessary, with sprayed concrete applied over these. Secondly the 3mm of Masterseal was applied and, after curing, followed by another layer of fibre-reinforced sprayed concrete of a minimum thickness of 60mm.

Holter explains that a specialist contractor was employed to apply the Masterseal 245. "As the tunnel is fairly narrow and tall it was decided to apply Masterseal manually. You need a specialist contractor rather than general tunnellers as there will be better concentration on quality rather than speed," commented Holter.

The owner is particularly interested in the performance of the sprayed membrane during the considerable variations in ambient temperature experienced, and also the transfer of heat between the tunnel air and the surrounding ground. Holter adds that it is known that installations in very high temperature tunnels elsewhere have been subject to thermal deformation requiring slight design modifications, so checks needed to be made on any possible variations needed in cold climates.

"The client was willing to note the advantages of sprayed waterproofing membrane over any perceived disadvantages, despite some opposition," says Holter. "And the result is a completely dry tunnel."

Sintef tests

Sintef is the largest independent research organisation in Scandinavia, and maintains links with industry and universities to develop technological solutions that are brought to practical use.

In order to test the actual heat transfer properties between the ground rock and tunnel interior across a sprayed concrete lining with Masterseal 345 double-bonded sprayed waterproofing membrane, Sintef has been carrying out a programme, supported by Jernbaneverket, to establish the properties of the combined layers. The balance of cold in a tunnel in winter, and the relative heat from the rock, may be crucial in maintaining the integrity of the lining and the waterproofing membrane. The concern is that groundwater in rock fissures connecting with the extrados of the lining could freeze, expand, and cause damage, but no such action has been determined, it is understood, due to the minimal heat loss preventing water freezing in the rock. So far the Sintef tests and the tunnel installation have confirmed that everything is going according to design intentions.

Down in the basement of the Sintef Building & Infrastructure Institute premises on the campus of the Norwegian University of Science and Technology (NTNU) in Trondheim, Prof Eivind Grov, Sintef chief scientist in rock engineering, guided this author through a collection of large-scale, mainly water-based, experimental apparatus to small twin rooms which form the test centre for tunnel lining thermal performance, believed to be the only facility of this kind in the world.

Blocks of local Storen granite cut to uniform size and representing the ground surrounding a tunnel separate the two rooms. The blocks' size is limited by the practicality of handling when installing. Each is 1.5m long, projecting into the 'cold' room representing the tunnel. Both rooms can have their temperatures maintained at require levels by air conditioning units and heaters. During testing the 'warm' room is kept at a constant temperature of 7-9°C to represent the ground temperature, which tends to remain stable. In the insulated 'cold' room the temperature is adjusted as required to represent the tunnel air temperature, using computer control, down to about -20°C. The computer controls the temperature in cycles to simulate natural conditions, and these cycles can be varied by the operator as required.

"As temperature and heat transfer fluctuations can take a considerable time," Prof Grov says, "the whole programme is necessarily lengthy."

Temperature sensors have been placed at seven intervals (20 to 1280mm from the cold room) through the rock mass with cable connections along the joints of the granite blocks. This allows the heat flux migration from one room to the other to be monitored to produce a series of data. There are 70 separate measurement points.

The granite blocks also accommodate four pre-drilled holes with hydraulic connections to a pump. These can be used to simulate the presence of water in the rock mass, up to the tunnel sprayed concrete lining, at pressures of up to 8 bar.

Between the granite rock mass and the 'cold' room, layers can be installed to represent the tunnel lining. In this case the layers consist of a layer of sprayed concrete, reinforced with polypropylene fibres, to represent the tunnel primary lining, the sprayed membrane of BASF Masterseal 345 bonded to it, and finally another layer of fibre-reinforced sprayed concrete, also bonded to the membrane. The three together are 125mm thick.

Roads

The use of sprayed waterproofing membrane has also attracted the attention of the Norwegian Public Roads Administration (Statens vegvessen) for future use in the country's trunk-road tunnels. However the Administration's requirements seem likely to be slightly different and discussions are currently under way on specifics.

Acknowledgements

T&TI is grateful to Christoffer Ostvik and site staff of Jernbaneverket, project manager for the contractor Betonmast (formerly Mika), Ulf Theander, and to Karl-Gunnar Holter of BASF Meyco for facilitating the visit to the Gevingasen Tunnel project. Also to Prof Eivind Grov for presenting the testing facility and providing additional information.

Further reading

Additional recent literature on this and related subjects includes:

Holter, KG & Nermoen, B. 'Permanent waterproof tunnel lining based on sprayed concrete and spray-applied double-bonded membrane', ITA World Tunnel Congress, Helsinki, May 2011

Holter, KG, Bridge R & Tappy O. 'Design and construction of permanent waterproof tunnel linings based on sprayed concrete and spray-applied double-bonded membrane', Proc 11th Int Conf of Underground Construction, 'Transportation and City Tunnels', Prague 2010, pp 571-574

Makhlouf, R & Holter, KG. 'Rehabilitation of concrete lined tunnels using a composite sprayed liner with sprayed concrete and sprayable waterproofing membrane; the Chekka road tunnel, Lebanon, Proc of World Tunnel Cong 2008, Agra, India, pp 1175-1182

Vassenden, S. 'Frost-laboratory testing of heat flux between tunnel and adjacent rock mass', MSc thesis, Norwegian Institute of Science and Technology, Trondheim, 2010

Leak sealing in brick-lined tunnels

Working with a rail trolley access platform in leak remedial work

The ingenuity of Victorian tunnelling engineers endures today in a network of tunnels for rail, canal, sewage and other utilities. Usually lined with multiple brick courses, many tunnels now leak. Peter Town of Hydrotechnics (H_2Ox) explains the role of polyurethane resin injection in remedial work

Whilst not too problematical on a canal or sewer system, leakage into a rail tunnel damages signalling equipment and causes corrosion to rails and overhead catenary.

If controlling or diverting ingress from over the tunnel crown can be achieved, it may be sufficient to overcome such damaging effects.

Remedial methods include fixing plastic membranes or corrugated sheets to the intrados, applying cementitious coatings, cement grouting behind the lining or resin injection into the brickwork. Internal physical barriers have several drawbacks and need maintaining, grouting behind the lining increases the load on the tunnel and may not seal active water flow paths. Since ingress predominantly occurs through open mortar courses, injecting brickwork with resin to fill flow paths appears to be a logical remedy. However, as with many civil engineering remedial situations, success is reliant on experienced, knowledgeable engineers selecting appropriate materials and devising logical work protocols. Get these wrong and any form of injection will be ineffective.

Two injection resins are commonly offered for leak-sealing – hydrophilic or hydrophobic, both are polymers. Hydrophilic resins are two-component, low viscosity liquids (typically acrylic) that react to form a gel, hydrophobic resins are mostly single-component polyurethane that are injected to make contact with leak water. On contacting water, the resin reacts to form cellular foam, both gel and foam block water flow paths and so control leakage. Of the two, hydrophobic polyurethane foam is more suitable for controlling leakage through brick linings than hydrophilic gels. The rationale is found in resin rheology, fluid dynamics, polymer flow, shear thinning, viscosity, pseudoplastic flow, molecular chain disentanglements, and other factors.

Site experience affirms the benefit of injecting hydrophobic polyurethane resin, free water inflows are arrested and dripping reduced, and overall injected sections visibly start to dry out.

A monitoring system exists for assessing the efficacy of resin injection into brick tunnels, the work area is surveyed before works commence and an assessment of ingress made and recorded. The evaluation is by objective observation against a Network Rail (The British railway infrastructure operator) scale of W1 to W5 using the following standards:

W1 = water ingress under pressure
W2 = water running
W3 = water dripping
W3i = isolated drips
W4 = damp
W5 = water staining

On a typical project, an inspection some two and a half weeks after injection confirmed that ingress had been reduced typically from W4 to W4/5 up to W2 to W4/5. A further inspection two years later endorsed the injection as effective. W4 on the leakage scale is the target value set by Network Rail to declare the injection process a success.

A successful result is not simply a matter of injecting a hydrophobic resin but is a comprehensively engineered solution. For example, as known proprietary injection resins were considered unsuited for use in a wet rail tunnel environment, a bespoke product was formulated, developed and tested. Given the brand-name Stabila P500, the new resin reacts to form a tough, flexible closed cell foam with a gentle reaction that inhibits delamination of brick courses. Stabila P500 was subsequently accepted by the UK Drinking Water Inspectorate for use in contact with potable water. Following accelerated testing of polyurethane foam in an alkaline environment, the life expectancy is extrapolated to be in excess of 75 years.

On a typical tunnel sealing project, 14mm-diameter injection ports are drilled in the brickwork by rotary percussive drills. Port spacing is calculated to provide resin spread through the open mortar courses between adjacent injection ports. Drilling is generally perpendicular to the intrados face and port depth relates to the number of brick courses, typically two thirds of the overall brick thickness. As the condition and uniformity of brickwork varies and customarily deteriorates at higher levels over the crown, the injection engineer may occasionally authorise a modified drilling pattern to substantially weakened sections. Injection packers featuring expanding rubber seals are then inserted and normally set in the second brick course.

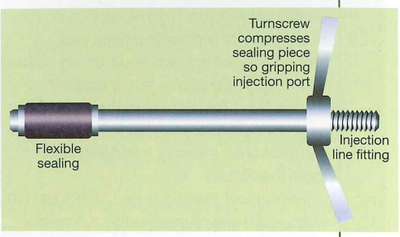
Above: **Inspecting for any remaining seepage following installation of polyurethane resin through the packers shown**

On injecting Stabila P500, water ingress throughout the work section visibly changes. Previously running inflows are arrested, dripping essentially stops and generally the area starts to dry out.

Injection is by air-powered piston pumps with pump pressure accurately controlled to slightly above pump stall pressure and just sufficient to overcome resistance in the injection lines. High pressure or high resin flow-rates are not necessary and may be detrimental to the structure. As distinct from cement grouting, resin injection protocol is not designed to 'grout to refusal', therefore peak pressure does not apply.

Void sizes in the mortar course directly affect the volume of resin injected to control ingress and such voids cannot be predetermined or quantified. The grouting procedure is monitored in real time to evaluate the grout flow over an area and the influence achieved. Resin take per injection port is not a constant value as open mortar course dimensions vary; such variation may lead to localised secondary and tertiary injection in some situations.

In conclusion, resin injection can be extremely successful in controlling water ingress through complicated water flow paths. However, understanding the concepts of comprehensively engineered protocols and appropriate injection resin requires a sound knowledge of the principles involved coupled with an empirical approach; unfortunately these are not gained in a classroom but learned through applied logic and experience.



Right: **Schematic of an injection packer**

‘Tommy’ Talbott, as he was known

Thomas A. Talbott (Tommy), a former director of Miller Tunnelling and Morgan Est Tunnelling (now Morgan Sindall Tunnelling), died on 12 June after a short illness. Tommy was 78, and in a career spanning nearly six decades working for the same tunnelling contractor, he had a guiding hand in many of the developments in best practice throughout UK tunnelling.

Tommy began his career in the early 1950s as an articled pupil to Sir James Miller and Partners working from its Hayes office in London. He was soon on site in Nottingham working on the Clifton Bridge spanning the River Trent. This was the first major pre-stressed in-situ concrete bridge to be constructed in the UK. Thereafter he was enlisted in the Royal Engineers, ‘the Sappers’ to complete his term of National Service, during which period he served as a 1st Lieutenant.

Upon demob in 1960 he returned to the Miller Group fold in what was then Miller Brothers and Buckley. He soon became involved in tunnelling projects, mostly small diameter tunnels and pipejacks and he was instrumental in pushing forward pipejacking systems, which were rapidly developing at that time. He often talked of his work at Sidcup—a typical tunnelling project of the 1960s comprising several miles of small diameter hand driven tunnels in compressed air accessed via vertical air locks, a technique long since surpassed by TBM tunnelling and unknown to younger, present-day tunnellers.

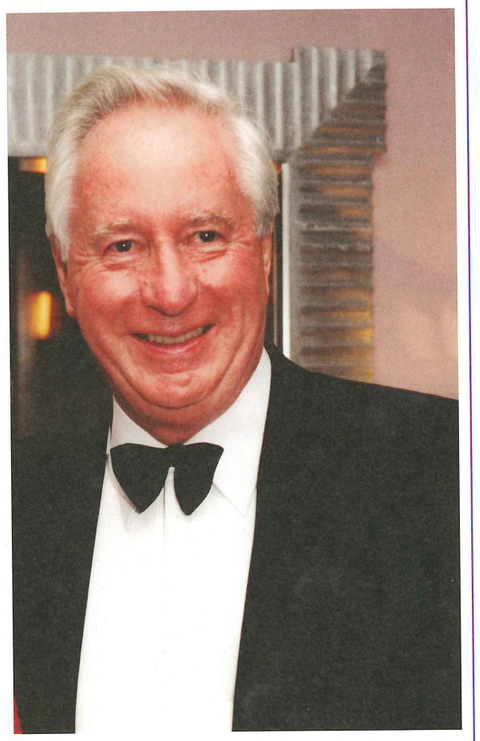
In the mid 1970s British tunnelling was beset by difficult industrial relations between the tunnelling contractors and the trades unions, which culminated in a prolonged strike in 1976. A joint committee of contractors and trade unions was formed to resolve the difficult issues before them. Tommy played a major part in this, soon gaining the respect of the trade union negotiators and as was his way, he maintained a strong friendship with them thereafter.

Throughout the 1980s and 1990s the old ways, such as compressed air tunnelling, had been left behind and modern TBM tunnelling methodology was ascendant. Tommy worked hard to ensure that his company was at the forefront of new construction techniques to have a competitive edge, which made Miller Tunnelling, subsequently, Morgan Sindall, one of the foremost tunnelling firms in the UK.

Among the projects that fell under his guiding hand, to name but a few, are London Water Ring Main, CTRL, Heathrow T5 tunnels and Kings Cross Underground Redevelopment. He also brought his knowledge and experience in supporting the development by Miller Tunnelling of the successful CombiShell sprayed concrete lining process.

Tommy was known by all who knew him as a gentleman. Always smiling, he never raised his voice, nor had a cross word for colleagues or competitors. His leadership was inspirational, especially for young engineers in his charge, many of which have become leaders in the UK tunnelling community. He loved to tell a story and, as an Englishman with a passion for cricket, he would tell anyone (over and over again) how he was trained by Trevor Bailey, the Essex and England all rounder, even though it was several decades ago!

He also had a passion for music and with his wife and friends he made many trips to Vienna and Innsbruck to attend summer concerts, perhaps pausing along the way to gather the latest developments in NATM from his colleagues at Beton and Monierbau with whom Millers joint ventured on the Heathrow Baggage Terminal leading to an enduring successful partnership.



Above: Talbott left a lasting impression on the industry and all who knew him

Tommy was a life-long supporter of the British Tunnelling Society, a committee member through the 1980s and vice-chairman in 1987; he was awarded the Society’s James Clark Medal in 2007 for a lifetime of service to British Tunnelling.

Tommy is survived by his wife and two daughters and their four grandchildren. There has been much comment by the leaders of the tunnelling industry in recent days about his life, his stories and his achievements. These can be summed up in one such short comment. ‘One way or another, he touched us all’.

The end of one man's era at Halcrow, marks a UK tunnelling legacy

When Alan Runacres, a director of Halcrow, retired in March a large number of Halcrow staff, past and present, attended to wish Alan well after 44 years with the company. Alan's wife Vivien, and their two daughters, Danielle and Lorette, were there too.

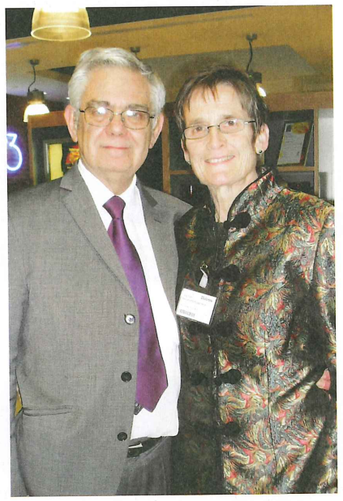
Alan joined Sir William Halcrow & Partners in 1966 from school as a sandwich student and during the next five years worked on remedial works to spoil heaps, the feasibility of light towers in the north sea and the design of the Royal Sovereign Light Tower at Littlehampton and projects connected with the Reservoir Safety Act. Alan graduated from City University in 1971, with a first class honours degree, and was awarded the Institution of Civil Engineers Graduate Prize in 1971.

After graduation Alan worked on complex structural and FE analyses on the Merrison Appraisal of Box Girder Bridges. The Deira Shindagah cut and cover tunnel in Dubai followed, together with the responsibility of co-ordinating the E&M and civil works. His first real tunnelling project was the design of the reconstruction of London Underground's Strand Station and later on the site supervision. Alan achieved his membership of the Institution of Civil Engineers in 1975.

For the next four years Alan then led a team on the design of the Ahmed Hamdi Road Tunnel beneath the Suez Canal, Egypt, and he was also responsible for the E&M design and co-ordination with the civil works.

Alan was promoted to a senior engineer in 1979 at the early age of 32, and provided specialist advice on the ventilation for several proposed road tunnels in Hong Kong. He also worked on the feasibility study for a major road tunnel crossing of the River Thames.

With the downturn in civil construction, in the early 1980s, Alan moved to the Hong Kong Office in 1982, under the impression that he would be working on a tunnel project. His projects were the design of a multi-storey luxury residential development, the design and supervision of a public housing development to accommodate approximately 22,000 people and a feasibility study for a 500 hectare housing resettlement in Brunei.



Above: Alan Runacres and his wife Vivien

He returned in 1983 and worked on the feasibility of the Great Belt crossing in Denmark, the design of sewer tunnels in the Royal Docks in London, emergency remedial works for London Underground, the East London River Crossing and redevelopment works at Liverpool Station for the Post Office Railway. The detailed design for port works at Stone Marshes lightened the tunnelling workload.

Alan was promoted to principal engineer in 1986 and implemented the Quality Assurance Policy in the Tunnels Department. He was project engineer for a number of major projects including Crossrail, the East London Rail Study, London Underground works at Victoria Station and the Jubilee Line, the rail link into Stansted Airport, preliminary design of the cut and cover tunnels for the East London River Crossing, safe guarding works for the Post Office and British Telecom and an audit for Eurotunnel of the ventilation and auxiliary services for the Channel Tunnel.

Alan was appointed chief engineer for tunnels in 1991 and a director later that year with the responsibility for soft ground tunnels.

Over the last 20 years Alan's role has been partly management related and partly project related. He was head of the tunnels department from 1994 to 1999. He has been project director, or provided technical advice, for many of Halcrow's major tunnelling and railway projects, including the early stages of Crossrail from Westbourne Bridge to Tottenham Court Station, the East London River Crossing, Rockcliffe Gardens and Plumstead road tunnels, the East London Line, London's Northern Docks Drainage, tunnels for the Bristol Bulk Handling Terminal, Northern Island Railway, works connected with the DLR and Northern Line direct link, the Channel Tunnel Rail Link, Bangkok Blue Line and preliminary design for the MRTA, Kuala Lumpur PUTRA LRT and Brickfields development, Maliakos road crossing, Manila Lines 1 and 2; and works in the UK including Woolwich Rail crossing, DLR to Lewisham, and other works for London Underground.

Alan cared about his staff and led them to ensure that they always got the right solution for a project. Likewise the staff respected Alan as did the industry. He was a great asset to the firm. He led from the front, but he always said that it was the work and effort put in by the team that made a successful project. Alan in retirement is unlikely to be continuing his engineering career, he can rest on his considerable achievements!

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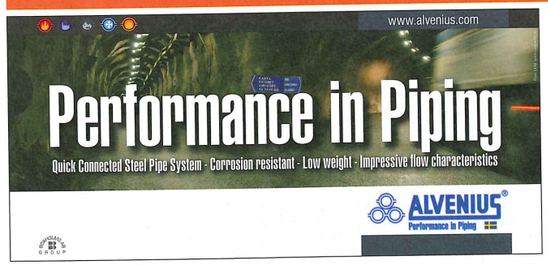

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dates & events

11 AUGUST 2011
Tunnelling & Underground Construction Society Course, Singapore
Suntec City Convention Centre, Singapore
Course covering key subjects related to safe construction undeground, including issues related to working in high-pressure compressed air.
For registration form contact TUCSS Secretariat, tel.: +6336 2328, Email: tucss@cma.sg or see www.tucss.org.sg

SEPTEMBER 2011
First MSc course in Tunnelling & Underground Space commences, Warwick University, England
Supported by the BTS and several leading industry suppliers, the degree course is accredited for the requirements for Further Learning for Chartered Engineer (CEng) for those who have already acquired a BEng(Hons) or similar.For further information contact Postgraduate Office, School of Engineering, University of Warwick, tel.: 024 7652 2046, Email: eng-pgadmissions@warwick.ac.uk or see web http://www.2,warwick.ac.uk/fac/sci/eng.pg/information

12 - 15 SEPTEMBER 2011
15th European Conf on Soil Mechanics & geotechnical Engineering, Athens, Greece
Organised by the Hellenic Soc for Soil Mechanics & Geotechnical Engineering on the them 'Geotechnics of Hard Soils - Weak Rocks' at the megaron Athens Intl Conf Center. Registration and assistance from Triaena Tours & Congress, tel.: +30 210 7499337 or +7499300, Email efip@triaenatours.gr or see www.triaenatours.gr. For scientific activities e-mail the Secretary on athens2011ecsmge@hssmge.gr

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

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

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

26-30 SEPTEMBER 2011
World Road Congress of the World Road Association (AIPCR/PIARC), Mecico City, Mexico
Includes a committee on road tunnel safety. For more information tel.: +52 (55) 5148 7500, Email: expo@aipcrmeexico2011.org or see www.aipcrmeexico2011.org

17 - 19 OCTOBER 2011
13th AFTES International Congress, Lyon, France
This three-day congress is organised by the French Underground Tunnelling and Underground Space Association (AFTES), with partner associations in Italy, Belgium, Spain, Portugal and Switzerland. Along with technical sessions and an exhibition there are seven site visits planned for the congress focused on underground space. Contact AFTES for more information: 15 rue de la Fontaine au Roi, 75011 Paris, Tel : +33 (0) 1 44 58 27 43

26 - 27 OCTOBER 2011
Underground Infrastructure of Urban Areas, Wroclaw, Poland
Organised by the Wroclaw University of Technology's Institute of Civil Engineering, the Polish Society for Trenchless Technology and the ITA-AITESA Polish group, this will be forum to develop an exchange of experiences and provoke a discussion on the topics related to building tunnels and underground infrastructure in cities. Contact Andrzej Kolonko, Tel. +48 71 320 2914 or email andrzej.kolonko@pwr.wroc.pl

6 - 8 DECEMBER 2011
STUVA Conference, Berlin
The 2011 biannual conference of non-profit research institute STUVA (the German Research Association for Underground Transportation Facilities) will focus on "Underground Construction for Sustainable Environmental and Climate Protection." New this year is a Youth Forum, an opportunity for young tunnel engineers to present. The winner of the STUVA young talent prize will be selected from the speakers, and awarded at the show.There is also an accompanying exhibition. More information available from www.stuva.de Email: info@stuva.de

8 DECEMBER 2011
T&T Internatonal Awards 2001, Berlin, Germany
Launch of this event that promises to champion the industry's best efforts, greatest achievements and most impressive recoveries. There are categories on overcoming adveristy,

A DATE TO REMEMBER...

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

14 - 16 MARCH 2012
ISTSS 2012, New York
The 5th International Symposium on Tunnel Safety and Security, organised by the SP Technical Research Institute of Sweden, will discuss themes of risk & security, human behaviour, construction, fire fighting and, ventilation. More info at www.istss.se

18-23 MAY 2012
World Tunnel Congress WTC 2012 & 38th General Assembly of the ITA, Bangkok, Thailand
Organised by the Thailand Underground & Tunnelling Group (TUTG) of the Engineering Institute of Thailand, the theme is 'Tunnelling & Undeground Space for a Global Society'. ABSTRACT SUBMISSION DEADLINE 31 August. Congress Secretariat: Zaw Zaw Aye on tel.: +662 3192 410, Email: secrtariat@wtc2012.com or see www.wtc2012.com

BRITISH TUNNELLING SOCIETY

15 SEPTEMBER 2011:
Crossrail
Status update. Latest developments on this major London project. Speaker: Andy Mitchell, Programme Director, Crossrail

20 OCTOBER 2011:
BTS / BGA Joint Event. Towards a Specification for the Ground - The use of Geotechnical Baseline Reports in the UK
Ground References Conditions. Details to follow. Speakers: Mike Black and Darren Page

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

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

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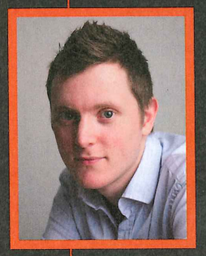

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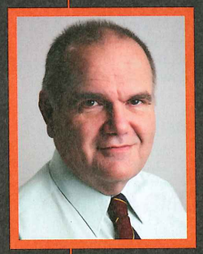

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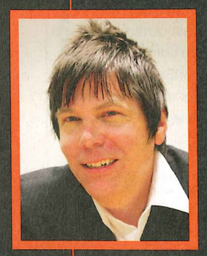

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