INTERNATIONAL EDITION
January 2017

Tunnels AND TUNNELLING

FREEZING RASTATT

Engineers face saturated ground in Baden-Württemberg

STONEHENGE SOLD SHORT?

Alex Conacher
The *Tunnels and Tunnelling* editor has been with the magazine since 2010

The Stonehenge Tunnel has reared its head once again. New plans have been green-lit by the government and it appears the shorter tunnel option, a 2.9km bore, is the favourite.

For readers not familiar with the project, the Stonehenge Tunnel is a long-delayed scheme to put the nearby A303 highway underground. While the supposedly mystical, 4,500 year old stones are worth a visit, the road adjacent to the stones ruins the experience. It is also one of the most congested routes in Britain and undergrounding is considered a necessary solution for expanding the road at the World Heritage Site.

An earlier push for the tunnel was defeated in 1996, and again in 2007 due to cost overruns. The second attempt also saw the National Trust state its preference for a 4km deep tunnel over the original 2km cut and cover vision. In July 2005, Roads Minister Stephen Ladyman announced a review of the options following a cost rise from GBP 284M (USD 505M) when the draft orders were published in 2003 to some GBP 470M (USD 836M). The increase was attributed to very large quantities of weak phosphatic chalk, and a high water table.

It is safe to say that initial reaction has been mixed, with many taking to social media to despair possible damage to the site, which has a footprint of 25 sq. km. The Stonehenge Alliance campaign group launched a petition in 2015 arguing that any tunnel shorter than 4.3km would do irreparable damage to a site that is still not fully understood. It achieved nearly 20,000 signatures so it remains to be seen if any action will be taken against the modern vision for the project.

While media is reporting that the plans have been finalised, there is still time to get involved. A public consultation, with a focus on drivers' needs, has opened and will conclude on 5 March. Readers should be able to access the consultation at: https://www.highways.gov.uk/a303stonehenge/consultation

Public exhibitions will be held at: The Manor Barn, Manor House, Winterbourne Stoke on14 January (11am-5pm); Antrobus House, Amesbury, on 18 January (2pm-8pm); Shrewton Village Hall, The Hollow, Shrewton, on 20 January (5pm-9pm); Avon Valley College, Durrington, on 21 January (11am-5pm); Larkhill School, Wilson Road, Larkhill, 24 January (5pm-9pm); Manor House, Winterbourne Stoke on 27 January (2pm-8pm); Salisbury Guildhall, The Market Place, Salisbury, 28 January (11am-5pm); Grove Hall, Mere on 4 February (11am-5pm); Burlington House, Piccadilly, on 6 February (2pm-8pm); Antrobus House, Amesbury, 8 February (2pm-8pm). The preferred route will be announced later in 2017.

Cover
The cover this issue shows ground freezing operations for the Rastatt Tunnel project in Germany

Next issue
In the next issue of *Tunnels and Tunnelling* we look at fit out works on the Crossrail project with a bespoke drill rig supplied by Rowa, the global problem of groundwater infiltration into existing sewerage networks and the safety of innovative vehicles in tunnels

This month...

20 YEARS AGO
Talks between the three countries directly involved in the proposed Brenner base tunnel project – Germany, Austria and Italy – were scheduled for December 1996. The main purpose was to formulate plans by the New Year for submission to the EC by resolving outstanding issues such as inter-operability of the tunnel, possible cost savings, sources of finance and models of partnership.
Tunnels and Tunnelling, January 1997 p.13

30 YEARS AGO
A new full face TBM has been ordered from Wirth of West Germany to help complete one of six troubled tunnel jobs on the ambitious Baikal-Amur Main (BAM) trans-Siberian railway in Russia.
Tunnels and Tunnelling, January 1987 p.7

40 YEARS AGO
Drifter wonders what 1977 has in store for the industry. Looking back on 1976 we can almost be forgiven for not having much hope. The frustrations of inflation and sporadic labour unrest have hit Britain particularly hard. We appeared to be both ill-equipped and ill-prepared to cope with either, nor could we find consolation in learning that the Australian and East Coast Americans have suffered longer and harder from this effect of restrictive practices of disorganised labour.
Tunnels and Tunnelling, January/February 1977, p.19

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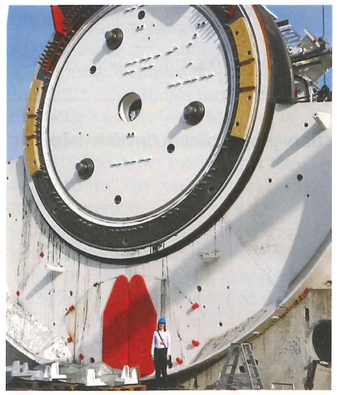

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UK COURT RULES AGAINST GLENDOE CLIENT

GREAT BRITAIN — A court has issued its ruling on the Glendoe collapse, finding in favour of contractor Hochtief at the expense of client Scottish & Southern Energy (SSE). The decision was given on 21 December and denied SSE a GBP 130M (USD 160M in Jan 2017) damages claim against Hochtief. The contractor will however have to pay low availability damages of GBP 1M (USD 1.24M in Jan 2017) for not completing the remedial work. Of particular interest from the court's conclusions is the placement of all risk on the client, despite the project being design and construct.

The ruling relates to the August 2009 collapse of a tunnel on the Glendoe hydropower scheme near Fort Augustus in Scotland. Eight months after take over by the client rock fell from the crown blocking the 5m-diameter tunnel. Operations did not resume until nearly three years later after completion of a 200m-long drill and blast bypass tunnel was completed by Bam Nuttall.

Jacobs was the client's engineering geology consultant, Donaldson Associates provided technical assistance on the recovery project and Pöyry was Hochtief's subcontractor for the design of civil works. Andritz was Hochtief's M&E subcontractor.

Initially client and contractor got together to discuss remedial works, however liability was a point of argument with neither party accepting responsibility for the rock fall. SSE was desperate to get operations running again as it was losing GBP 50,000 per day, hence the decision for a bypass.

The contractor contended four points: that it had completed the works in accordance with the contract, that the owner assumed the risk of collapse at takeover, that the scope and cost of the recovery was unreasonable and that it was entitled to carry out remedial works.

The judge identified that the core of the matter was a simple issue: "Did the contractor misclassify the rock and in consequence fail to install the correct support? The owner submits that the answer is 'yes'. The contractor takes the opposite position."

Jacobs expected 97.5% of rock to be 'good' but warned that information was scarce. One fault zone, the 'Conagleann Fault Zone' would have required the UK's largest drilling rig to bore, and there was no access road or helicopter that could get it into position, so it was left uninvestigated, despite a Hochtief request to the contrary. Eventually SSE awarded a contract to Hochtief, which went with a TBM observational approach with four support classes (Class I being minimal support). It stated that it expected 60 per cent of the tunnel to be unlined.

During tunnelling, rock conditions were judged to be very dry and good, with very few weak sections and requiring no forward probing. Both SSE and Hochtief had geologists working to continuously agree rock classification.

The following table shows the use of various support classes on the total drive, showing that conditions appeared to be better than expected.

	Expected	*As Built*
Class I	58.9%	84.3%
Class II	23.1%	15.4%
Class III	14.3%	0.3%
Class IV	3.7%	0%

Even when passing through the fault zone, where special care was taken including removing the probe drill to improve rock bolting efficiency, no particular challenge was encountered. Crews reported barely noticing the fault.

Prior to 'watering up' the tunnel, the parties conducted a walk through to carry out metre-by-metre inspections of the tunnel to detect any problems and decide if additional support was needed anywhere. Some areas were upgraded from Class I to Class II and Pöyry recommended the application of shotcrete strips and mesh to certain areas of erodible rock. Professor Broch inspected the headrace and reported: "My general impression was that the rock mass conditions in the tunnel are very good. It is one of the driest tunnels that I have ever inspected ... No major weakness zones were observed ... The weakness zones described in the Pöyry report are all small, and as far as I could observe, none of these may cause serious collapses. I thus regard the support measures recommended in the report as being more than good enough for a tunnel that is basically designed and built as unlined."

Aside from a few minor comments, the tunnel was accepted and takeover certificate issued in December 2008. Hochtief was paid GBP 2M (USD 2.47M in Jan 2017) for early completion and an additional GBP 5M (USD 6.2M in Jan 2017) for variables. There was due to be a final inspection two years later.

In early summer 2009 oddly low water and power readings were detected, but operators assumed calibration problems at first due to the newness of the site. With hindsight this was seen as a mistake. By late 2009 sediment plumes were observed being pumped into Loch Ness. In August 2009 the plant could not even reach 100MW and senior SSE personnel were "shell-shocked". A subsequent dewatering and walk through found rockfall in the headrace. It was then decided to construct a bypass.

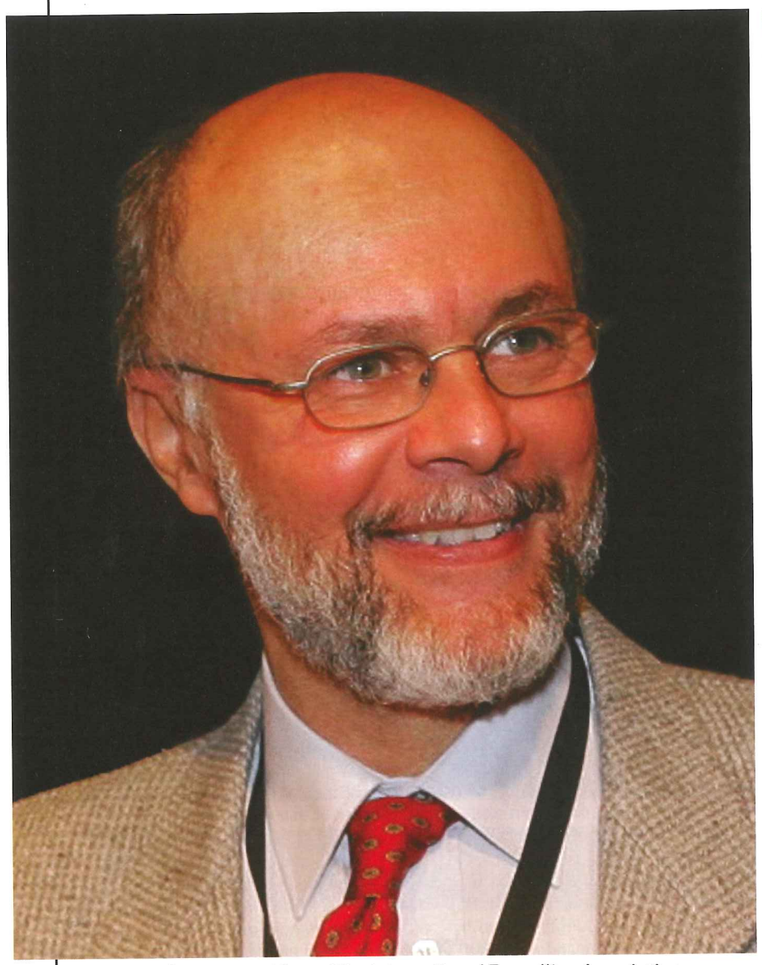
It was judged that the reason for the collapse was that there was not enough support; poor rock conditions coincided with insufficient shotcrete and rockbolts. There is a paucity of detail here according to the judge as no full investigation took place, one being redundant following the decision to construct a bypass.

The blocked zone is 71m long and the collapse developed progressively from at least 12 April 2009. It is not know what length of crown collapsed or the dimensions of the void.

The judge concluded: "**a)** The contract imposed a duty on Hochtief to exercise reasonable skill and care in the construction of the scheme. **b)** Hochtief discharged that duty. **c)** The ground conditions were worse than it observed, however, and the support proved insufficient to prevent the collapse. **d)** Class IV support was required to prevent the collapse. **e)** The collapse was not due to a defect that existed at take over. Accordingly, it was an employer's risk event. **f)** There was no contributory negligence. SSE was not at fault in respect of the odd readings and output swings from April to August 2009. **g)** Hochtief did breach its obligations by not returning to repair the tunnel. **h)** In consequence **(i)** SSE was entitled to instruct BAM to carry out the recovery project, and **(ii)** Hochtief is not entitled to recover any sums in terms of the counterclaim. **i)** If I had been awarding damages to SSE on its principal grounds of action, I would have held that the costs of the recovery project are reasonable, subject to deletion of the claims in respect of the 'secondary tunnel defects' and the dam bottom culvert. I would have also considered deducting a sum to reflect low productivity in the early months of the project. **j)** I am minded to award low availability damages to SSE."

An SSE spokesperson said: "SSE is disappointed with the ruling on the compensation claim. We will review the decision and assess our options."

ITA'S PRESIDENT SENDS NEW YEAR MESSAGE



Tarcisio Celestino, president of the International Tunnelling Association

GLOBAL — Tarcisio Celestino, president of the International Tunnelling Association, delivered the following message in early January.

In spite of an overall low level of global economic activity, the tunnelling industry seems to have been growing steadily along 2016. This is an indication of the effectiveness of underground solutions for infrastructure being more and more recognized by decision makers. Contributions of ITA Working Groups and Committees can be traced in this trend with respect so the promotion of the use of underground space; the significant improvement of operational safety standards when compared to the situation in the late 1990s; better relationship between owners and contractors due to improved contractual practices; technical innovations and their dissemination amongst practitioners; the benefit of construction and operation risk assessment; etc.

The World Tunnel Congress (WTC) held in April in San Francisco was a landmark success. It attracted the record figure of 2,300 attendees. This means that many more people have been exposed to a WTC and all the positive effects of information dissemination and networking are yet to be realized. The program covered a very wide range of topics, including sessions on high-tech development for tunnel construction and monitoring.

The new Executive Council elected late April in San Francisco started to work immediately after. We met in Napa addressing important issues, including the revision of the strategic plan to be presented at the next General Assembly in Bergen.

With respect to knowledge sharing, a new procedure for reviewing ITA publications was approved. It is expected to have a positive impact not only on expediting the reviewing process, but also on the quality of technical contents of the publications.

The ITA Tunnelling Awards Ceremony held on November 11th in Singapore was very successful. This can be measured not only from the standpoint of a significant increase in the number of attendees compared to the previous year (about 75%), but mainly because of the high quality of the presentations by the finalists and the relevance of some contributions. The event can be considered fully consolidated after the 2016 edition. Not only does it promote the excellence in tunnelling, but it also brings incentive to innovation, safety initiatives, fair contractual relationships between owners and contractors, etc. I am sure that in the long run the event will significantly contribute to demonstrate with a number of successful case histories that tunnels can be reliable and predictable for infrastructure construction when the correct practices are adopted.

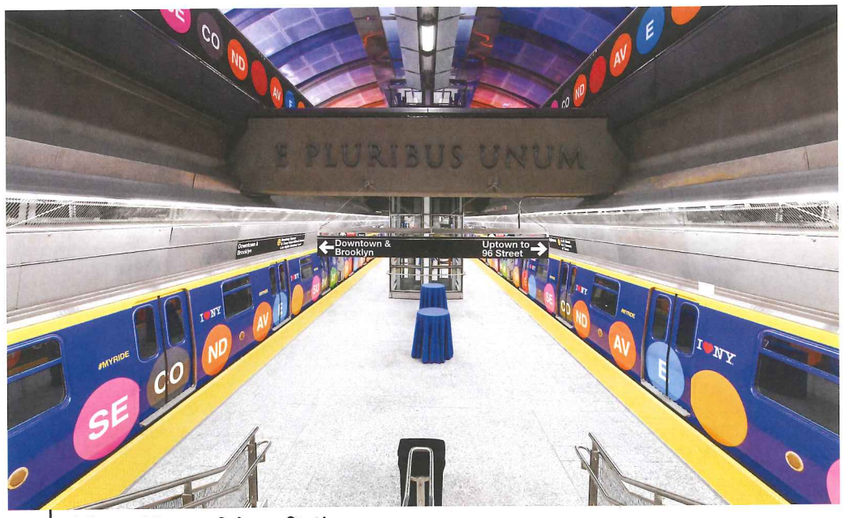
The Tunnelling and Underground Construction Society of Singapore organized a conference on innovation and productivity the day before the Awards Conference.

The synergy between the two events attracted even more attendees. Alan Chan, Chairman of the Land and Transport Authority, was the guest of honours at the awards banquet.

The Awards Committee is already working for the preparation of the next event in Paris in November 2017. Information about the third edition of the event will be available soon.

It is clear now that there is room for the two regular major events (WTC and Awards) attracting even different types of attendees.

Now it is time for all of us to pause for the New Year celebration. I wish you all a prosperous 2017 and look forward to our get together for the WTC in Bergen next April, when we will welcome Nigeria and probably Oman as new Member Nations.



A Second Avenue Subway Station

Second Avenue Subway starts service

USA — A century of planning and construction reached completion on January 1 as passengers took the first rides on New York's Second Avenue Subway.

Governor Andrew Cuomo hosted an event on December 31, 2016, to celebrate the on-time arrival of the project, which is the system's first major expansion in more than 50 years.

"They talked about the Second Avenue Subway 100 years ago, literally, and then in the '40s they knocked down the elevated line that was on Second Avenue and Third Avenue because they were going to build the Second Avenue Subway," Cuomo said.

"They just forgot to build the second avenue subway."

He thanked all the contractors involved in the new subway project and said, "they really, really made a superhuman effort to get this done on time."

This is the first of four phases for the Second Avenue Subway. Phase One entailed a two-track line connecting 105th Street and Second Avenue to existing services at 63rd Street and Third Avenue, with new stations at 96th, 86th and 72nd Streets.

Future Phases Two through Four will complete the line from 125th Street down to Hanover Square in lower Manhattan with 16 new stations.

A Skanska, Schiavone and Shea joint venture (S3 Tunnel Constructors) had the contract to build new tunnels between 92nd and 63rd Streets, excavation of the TBM launch box and excavation of access shafts at 69th and 72nd Streets.

Port Authority earmarks funds for Gateway Tunnel

USA — The Port Authority of New York and New Jersey announced Friday, January 6, it has issued a USD 32bn draft capital plan with USD 2.7bn set aside for the Gateway Tunnel program.

The agency, calls the 10-year plan unprecedented, and will release it for public review in the upcoming days.

"This region needs new and upgraded transportation infrastructure to deal with regional growth," said Port Authority executive director Pat Foye. "This ambitious plan proposes to invest billions to maintain the agency's world-class bridges, tunnels, airports, seaport and PATH system in a state of good repair while continuing to rebuild and expand existing facilities and build new ones to meet the region's growth."

The Gateway program is a series of rail infrastructure improvements, including a new, two-track Hudson River tunnel. The USD 2.7bn will go toward the payment of debt service for the Trans-Hudson rail tunnel link between New York and New Jersey. That includes an already approved USD 302M toward debt service on the Gateway Development Program's Portal Bridge North project.

NEW TUNNELLING STANDARDS TO BE PROPOSED

NORTH AMERICA — The American Society of Mechanical Engineers (ASME) is working on putting forth standards for the tunnelling industry. During a meeting held in October by the American Society of Mechanical Engineers' Pressure Vessel for Human Occupancy (ASME PVHO) Committee, ASI Marine's (ASI) Hyperbaric Tunnelling Specialist, Jerry East was nominated and awarded a position on the Diving Subcommittee. East has extensive experience in compressed air tunnelling, commercial diving and marine construction. He will serve as both a Diving Sub-committee member and an active member of the Tunnelling Task Group.

In the next few months the new proposed tunnelling standard is expected to be considered by the ASME PVHO Main Committee as a "Code Case". A Code Case is effective immediately upon ASME approval, therefore considered the quickest, most efficient way for a new standard to be set in place. If the committee approves the code case, it effectively becomes part of the ASME Standard.

In Canada, ASI's Stu Simms, Operations Manager in Vancouver, is involved in the standards industry for the tunnelling market as an active voting member on all CSA z275 diving and tunnelling committees and, Chair for the CSA z275.3 Committee for Compressed Air and Pressurized Environments.

ASI continues to be an industry leader by actively participating in both organizations and contributing to regulatory standards that protect the health and safety of both employees and clients alike.

The next edition of the American Society of Mechanical Engineers PVHO Standard is due to be released in 2019.

Brokk acquires Aquajet

SWEDEN — Equipment manufacturer Brokk has bought out Aquajet, a leading manufacturer of hydrodemolition machines, primarily known for use in concrete renovation works.

There will be no reorganisation of the companies, management structures will remain as they are.

"By becoming a part of the Brokk group, we can now accelerate the global growth of Aquajet", said Roger Simonsson, Managing Director of Aquajet Systems.

"With the acquisition of Aquajet Systems, the Brokk group further strengthens its leading position in providing world-leading machines for the concrete demolition and renovation businesses," says Martin Krupicka, CEO of Brokk Group.

Mini Cam expands into Latin America

LATIN AMERICA — Pipeline inspection equipment supplier Mini Cam has appointed its first Latin American distributor. Spain-based Mejoras Energeticas gives Mini-Cam access to markets in Argentina, Mexico, Panama, Costa Rica, Nicaragua, Honduras, Belize and El Salvador.

The company will also handle servicing and spare parts.

International sales manager Sven Breitenfeld said: "Following our launch of new product ranges earlier this year, we have an excellent opportunity to grow our overseas business.

"Countries in Central and South America are developing their infrastructure at a rapid rate. Their cities are growing fast, and that is leading to increased demand for fresh and clean water and huge investment to improve their sewer networks.

"Alongside that, pollution and water issues are on the wider political agendas in those regions, so it is important for us to have a presence there."

BTS modelling soil structural interaction seminar

Don't forget to register for the joint NAFEMS/BTS one-day seminar on modelling soil structural interaction during tunnel excavation on 23rd February 2017 at the University of Warwick.

This seminar will focus on numerical modelling of the complex interaction between soil and structure during tunnel excavation. This is a major talking point currently, with over 26 miles of tunnels being built under the UK's capital city as part of Crossrail and numerous London Underground Station Upgrade projects.

Ensuring that the tunnels are correctly designed is essential to ensure the safety of those involved in the tunnelling operation as well as ensuring that life above ground carries on without interruption. The event will focus on modelling of the soil-structure interaction behaviour in tunnel construction, with an emphasis on sprayed concrete lining. BTS Members can attend for GBP 50 for the day.

For bookings please go to the NAFEMS website:

https://www.nafems.org/events/nafems/2017/simulating-soil-structural-interaction-during-tunnel-excavation_/

See more details on page 36 of this issue.

WORK BEGINS ON NATIONAL GRID'S THAMES TUNNEL

FP McCann pipes lowered down a shaft for National Grid

GREAT BRITAIN — Engineers were preparing to sink 30m deep shafts at locations alongside the Thames in West London as *Tunnels and Tunnelling* went to press. The sites were being prepared at the Royal Hospital Chelsea, Battersea Park and ahead of construction of the 330m-long tunnel by micro TBM.

The first shaft, which will have a diameter of 7.5m, will be sunk in the grounds of the Royal Hospital Chelsea between January and March 2017. The site will then be cleared to avoid any disruption to the events over the summer. Work will then shift to Battersea Park where the second shaft – with a diameter of 6m – will be sunk between April and August 2017. Tunnelling will start after the shafts have been completed and should be finished in 2018 after which the new intermediate pressure gas pipe will be installed.

The project is part of a National Grid scheme to future-proof London's gas infrastructure.

Project Manager Andrew Hejdner said: "This is National Grid Gas Distribution's flagship civil engineering project for the 2013-2021 regulatory period. We're looking forward to getting started on the construction which has taken almost 12 months of planning."

He added: "Designing a tunnel 330m long tunnel that runs 30m under the River Thames is fairly straightforward in tunnelling terms however to secure so many permissions and factor in Thames Tideway's works in such a short space of time is an impressive undertaking. Our project team have done a fantastic job in designing the river crossing and securing the necessary permissions."

National Grid Gas Distribution's strategic partner Triio, which also includes Mott Macdonald and Skanska, will deliver the project.

Left: Two Terratec 6.61m-diameter EPBMs made an historic double breakthrough on 14 November, marking the end of tunnelling works on the 58.6km Pink Line (Line 7) on Phase III of the Delhi Metro project in India

IN THE FAMILY

Paola De Pascali visited Rocksoil's headquarters in Milan to talk Giuseppe Lunardi about the history and development of Rocksoil. Also included is a Q&A with Lunardi's father, Pietro Lunardi, in which he notes the emerging potential for underground power plants

Left: Giuseppe Lunardi, left, and Pietro Lunardi, right, of Rocksoil

PIETRO LUNARDI FOUNDED ROCKSOIL in 1979 to provide design, consultancy and technical assistance for civil engineering projects. His son, Giuseppe Lunardi, is Rocksoil CEO and managing director. He explains the setup of the company.

"Rocksoil Engineering is the holding company of the group which has two subsidiaries, Rocksoil and Tre Esse Engineering," Giuseppe says. "Tre Esse offers onsite geotechnical and structural monitoring. We also have a 65 per cent stake in the Earth System company, which designs and manufactures the equipment, data loggers and software for geotechnical, environmental and structural monitoring. They typically combine for contracts, but Tre Esse and Earth System can also work on behalf of a third party."

Among the company's latest projects is the new highway connecting Bologna with Florence. This work is included in the Variante di Valico project, which is led by Autostrade per l'Italia. The company has also designed several Italian metros such as Brescia, Milan (Linea 4 and 5 and parts of Linea 3), Genoa, Rome B1-C and Naples. "The majority of these works are carried out by integrated contracts so we work as contractors' designers," Giuseppe says, adding there is continuous demand for this kind of work. "Even if many cities have already built underground facilities, they need to update their network."

Some of our ongoing projects further afield from Italy include: the Cityringen in Denmark, the Al Diwani metro station in Qatar, the Riyadh metro project in Saudi Arabia and the D1 highway in Slovakia.

FOREIGN HOPES

The company is targeting foreign markets and is tendering for underground contracts in Brazil. "I think the South American market may be relevant for the tunnelling sector because of the need to invest in infrastructure in that area." Giuseppe adds, "Iran is another important market, which, thanks to its extensive mountainous area, requires a lot of infrastructure for metropolitan, railway and road projects.

"We have also had success in Russia for the Sochi 2014 Olympics. We drew up the construction project for Sochi bypass and provided the technical assistance on site during construction."

Among the tunnels built for the bypass, galleries T8 and T8A were quite challenging due to the extreme geological conditions (see *Tunnels and Tunnelling* December 2016). Thus, works had to be performed at the length of the track underground (1.55km for the tunnel T8 and 1.523km for the tunnel T8A) and to the size of the excavation sections, which vary from 120 sqm to 220 sqm. The cover on the tunnel cap reaches 75m in the northern sector, but it is low on the average and within a heavily urbanised environment.

"Unfortunately, Russia has been affected by a strong recession and the depreciation in commodities has slowed down many projects. However, the market is showing some slight signs of recovery," Giuseppe says.

"The US market is making a comeback in the tunnelling sector because they understand the value of utility investment. Even if North America doesn't need as many tunnels as Europe, there could be the impetus to invest in underground projects due to the expansion of urban areas. It's also well-known that Americans use old-fashioned tunnelling techniques so we think it could be a good opportunity to show off our expertise."

However, Rocksoil's strongest market is northern Europe, including Scandinavia, Germany and France.

Regarding the Italian market, Giuseppe says there has been a contraction over recent years. "We are now completing

Paola De Pascali
Paola joined the *Tunnels and Tunnelling* team in 2016 as a contributing editor

works which started 10 years ago, but previous governments didn't plan any infrastructure work. Despite this, we have started to see a slight increase of roughly 20 per cent in investments for the tunnelling sector.

"We are also waiting for European Commission approval for some corridors between Italy and Europe such as Turin-Lyon and Brenner."

There will be also new lines related to a high-speed project to connect each part of Italy. "The AV/AC Line is ongoing to link Naples and Bari in the south of Italy," Giuseppe explains.

"Another project is the Messina Strait bridge in Sicily, which will boost southern Italy's economy.

"Rocksoil would not be involved in the suspension bridge design, but we would design the tunnel system, including both road and railway networks to ensure access onto both sides of the bridge.

"As there is seismic risk in that area, the suspension bridge has been designed, based on calculations, models and tests on a small scale, to withstand potential earthquakes," Giuseppe says. "The 'elastic' structure can support every kind of seismic event. An excellent example of an earthquake-resistant bridge is the Akashi-Kaikyo in Japan, which is the longest suspension bridge in the world with a span of 1.99km. The Messina Strait should be 3.3km long with towers of 382.6m height, which should be taller than Akashi-Kaikyo's towers of 297.3m height."

Italian prime minister Matteo Renzi has revived plans for this bridge, saying the roadway across the Strait of Messina would be economically beneficial for the country. The total cost would be roughly EUR 9bn (USD 9.34bn).

WORLD TUNNEL CONGRESS 2019

Giuseppe is vice-president of Italian Tunnelling and a member of the International Tunnelling Association (ITA) and is looking forward to his homeland getting to host the World Tunnel Congress in 2019.

"I think that WTC 2019 in Naples will be a good opportunity for Italy to show its resources to the rest of the world," he says. "Our main competitors were big cities like London, Istanbul and Salzburg. We worked hard to introduce our candidature to the 78 national members of the ITA and we are proud of being successful. This congress will be important to make our politicians understand the value of underground space. As a result, they should invest much more in underground facilities to get economical and environmental returns."

Q & A WITH PIETRO LUNARDI

The leader of Rocksoil, and father of Giuseppe Lunardi, is a respected and experienced figure within the tunnelling industry. Here the former Italian cabinet politician shares career highlights and current thoughts.

WHEN AND WHY DID YOU DECIDE TO BECOME AN ENGINEER?

The decision to pursue my studies in civil engineering was due to my innate vocation for the natural world. Designing civic works allows you to protect the natural balance of the earth's crust. My reference points are natural balances, which constantly drive all of my professional choices.

AFTER BEING INVOLVED IN POLITICS AS A MEMBER OF PARLIAMENT AND SENATOR FOR MANY YEARS, WHAT CAUSED YOU TO RETURN TO ENGINEERING?

I strongly believe that I can serve my country much better as a designer of underground works than as an MP.

WHAT HAS BEEN THE HIGHLIGHT OF YOUR CAREER?

Always respecting nature allowed me to achieve great results and successes during my career. This is for me the biggest achievement.

HOW HAS THE TUNNELLING INDUSTRY CHANGED THROUGHOUT YOUR CAREER? WHAT HAS CHANGED FOR THE BETTER, AND HAS ANYTHING BECOME WORSE?

The tunnelling industry has changed markedly over the last 30 years. Big improvements include not just mechanised excavation methods, but primarily the project approach, which aims to plan everything in advance before starting underground works. This kind of approach ensures safe working and avoids money and time being wasted in the construction works.

What is becoming worse is the attitude of some tunnelling designers, who are not always able to keep up with the latest innovations.

WHICH PROJECT WOULD YOU SAY HAS BEEN A HIGHLIGHT FOR YOU?

I would mention two: the underground railway in the central areas of Milan, Viale Regina Giovanna, and the high-speed railway, which connects Bologna to Florence.

The first is a 260m-long stretch of rail, which is part of the Passante railway in the East-West side of Milan. The width of excavation is 30m with a maximum cover of 4m. The tunnelling works were carried out under ancient buildings along alluvial and unstable lands located under the aquifer level.

We opted for a bored tunnel to avoid any disruption and impact on road traffic and managed to achieve superficial settlements of 14mm.

The Bologna-Florence railway included the realisation of 104km of tunnels on a 78km route. This railway consists of a double-track tunnel with a width of 12.8m and it was excavated by traditional methods.

Following the Analysis of Controlled Deformation in Rocks and Soils (ADECO-RS) approach, we were able to avoid every kind of problem. Work took place between 1997 and 2005 and was completed on time despite poor geological, geomechanical and tectonic conditions.

TECHNOLOGY IS ALLOWING MORE SOPHISTICATED AND MORE CHALLENGING PROJECTS TO BE REALISED – FOR EXAMPLE THE BASE TUNNEL PROJECTS OF RECENT YEARS. DO YOU EXPECT TO SEE TUNNELLING USED IN ANY OTHER NEW SETTINGS?

The tunnelling sector needs to achieve further improvements. Of course, carrying out big projects can lead us to develop new technologies. Nowadays the demand is closely related to the safety of tunnelling workers and optimisation. Optimising a project is the best solution to save money and time in construction and maintenance. Thus, I think that these topics will drive engineers to improve their projects in the near future.

WHAT ARE YOUR THOUGHTS ON THE STRENGTH OF THE ITALIAN TUNNELLING MARKET?

As tunnelling experts we developed new technologies, which allowed us to work with unstable lands. So far we've managed to excavate even in the hardest stress-strain conditions. We always advance in full-face and ensure as much safety as there is when working in good rock conditions.

DO YOU THINK THAT STATE OF THE ITALIAN ECONOMY IS A THREAT TO TUNNELLING?

The economic growth of countries depends on the quality of the public transport network. That means the need to plan this network in the short and long-term. Even if Italy has been affected by a strong recession, we are still seeing opportunities for infrastructure investments and, as a result, for tunnelling.

WHERE DO YOU SEE TUNNELLING WORK COMING FROM IN THE FUTURE?

Land use for building construction and infrastructure is reaching a dangerous level for the environment, especially in industrialised countries. In Italy 6 to 7sqm of land are used up every second. This is clearly unsustainable and so we will increasingly be forced to consider underground, in which can offer huge spaces, as the 'fourth dimension'. In that way, we can avoid a lot of problems related to the quality of life above ground, and ensuring the safeguarding of the environment as well.

Placing power and nuclear plants underground could reduce or even completely solve any environmental issues related to this kind of infrastructure, which nobody would like to have near their homes. The underground solution can also be applied to store energy from other sources like water or solar, and for disposal of hazardous waste at a depth of more than 200m.

I have been working on this project with Carlo Rubbia, an Italian particle physicist and inventor who shared the Nobel Prize in Physics in 1984 with Simon van der Meer for work leading to the discovery of the W and Z particles at CERN.

After carrying out an accurate cost-benefit analysis, we realised underground power plants are a valid alternative to those placed above ground.

Costs can be halved for both installation and decommissioning of the power plants. There won't be any risks of radioactive emissions into the atmosphere as happened in Ukraine and Japan. For example, underground spaces beneath mountains could not be affected by this type of emissions because radioactivity doesn't reach such depth, changing the route of neutrinos and other infinitesimal particles. Regarding earthquake issues, utilities placed underground transmit seismic waves without being damaged.

I'm sure this can be the future for tunnelling workers. Carlo and I will be studying and researching to realise our project. Even Andrei Sakharov – the Russian nuclear physicist and activist for peace and human rights – said the future for safe energy should be projected towards underground nuclear plants.

Of course, the strong lobbyists for above ground power plants don't like this project, but we keep going with our plans. We are going to propose our project to Armenia, which will need to redevelop the reactor in Metsamor, which is in a seismic area.

We can show them that they can save money and time by placing a new power plant underground.

HOW MUCH OF THE TUNNELLING WORK IS RENOVATION/REPAIR, COMPARED TO NEW PROJECTS?

First of all, underground works require much less maintenance than those built above ground. With renovation it's necessary to update signage and lighting to modern standards in addition to building up new works from those existing. An example is the Variante di Valico highway A1, which connects Bologna to Florence.

Other opportunities for the renovation sector come from the "Nazzano method" for widening roads, motorways, main lines and metro rail tunnels without interrupting road and railway traffic. I developed this method to widen the Nazzano twin bore tunnel from two to four lanes in each direction. The 337m-long tunnel is located on the Milan-Rome A1 motorway.

The Nazzano method can be used to widen the old Montedomini tunnel on the A14 highway towards Senigallia.

Wherever confined spaces prevent carrying out any variations to the existing works, we can adopt this method.

WHAT ARE THE CHALLENGES FACING YOUR COMPANY AT THE MOMENT?

We need to spread the technologies developed over the last 30 years all over the world, showing the benefits in terms of costs and time saved by applying the correct tunnelling methods.

I had the opportunity to talk about that during the Muir Wood Lecture at World Tunnel Congress 2015 in Dubrovnik.

WHAT IS YOUR VISION FOR YOUR COMPANY? WHAT ARE YOUR PLANS FOR THE FUTURE?

I'd like Rocksoil to keep on accepting new challenges in the future. This spirit led us to design many important projects in addition to offering technical assistance in ongoing works.

So far we have done that for a total of 1,200km of tunnels, of which 800km have been excavated with the traditional method and 400km with the mechanised method. The majority of these works have been designed and carried out in Italy, but we have also started working abroad over the last few years. Foreign markets appreciate our knowledge and experience in tunnelling, especially our ADECO-RS approach

FUTURE DOWN UNDER

Tunnels and Tunnelling speaks with Rob Muley, general manager for tunnelling at John Holland to get his views on the company's place in its home markets

NOW THAT THE MIDDLE East is coming off the boil (somewhat); friends and colleagues have begun jetting off to new projects and lives around the world. One place in articular stands out as the new hotspot for tunnelling activity: Australia.

But just how large is the coming boom in the sunburnt country? For Rob Muley, general manager for tunnelling at locally based contractor John Holland, the pipeline of work has never been better.

"We have the best market that I have ever seen in my 30 years in tunnelling and getting the skilled labour in to the market is actually a challenge. It's going to be a real strain on the existing resources in tunnelling experience.

"We are having a lot of interest from all over – the Middle East, the UK, everywhere. A lot of interest in the market here, but I think fundamentally we are going to be stretched as an industry, particularly when it comes to labour."

PROJECT PIPELINE

The work really is extensive. Following the completion of the impressive 15km Sydney Metro Northwest tunnels between Bella Vista and Epping early in 2016, there is the ongoing twin 22km of tunnelling for the AUD 12bn WestConnex road project in Sydney; the twin 9km tunnel NorthConnex coming up also in Sydney for another AUD 3bn; the twin 1.5km Western Distributor in Melbourne, a six-lane road tunnel, is in tender for AUD 5.5bn, although this includes a bridge; the AUD 11bn Melbourne Metro is also tendering and is looking like twin 9km tunnels; the twin 11km Harbour Link road tunnel and the 10km South Link in Sydney are also on the horizon; and the nation's surprise 8km twin rail tunnel, which forms part of the AUD 2bn Forrestfield-Airport Link (in the spacious, low-density city of Perth) is also underway. According to Muley there is also talk of a couple more tunnels for Melbourne.

STABLE IN SYDNEY

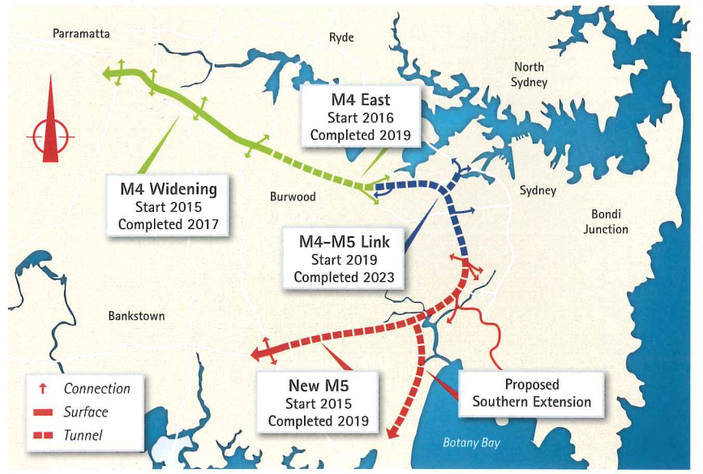
For John Holland and Muley, tunnel construction work on the Sydney Metro North West rail tunnels (single contract for twin tunnels each 15.5km long excavated by four TBMs and four underground stations) is complete, with the project moving into fit out and due to commission in 2019. The company is still heavily involved in Sydney however, with work ongoing for WestConnex M4 East, a twin three-lane 5km tunnel driven by roadheader. John Holland is also tendering for WestConnex M4-M5 Link early this year, another multi billion dollar project. John Holland recently submitted a tender for the tunnel section of the second stage of Sydney Metro (Sydney Metro City and South West). This stage includes twin running tunnels each 15km long and six underground stations between Chatswood on the north side of Sydney Harbour and Sydenham on the south side.

Work in Sydney for road tunnels is typically carried out by roadheader unless there are serious water concerns and is predominantly in the stable Hawkesbury Sandstone or Ashfield Shale. Over 50 roadheaders (300 kW) will be in operation across Sydney over the next two years.

Rail and water tunnels are generally constructed by open face TBM through the Hawkesbury Sandstone and Ashfield Shale. The exception being a 5km long section the New Southern Railway which was constructed for the 2000 Olympic Games to provide a rail link from the city to the airport which was excavated by a 10.8 m diameter slurry TBM.

***Above:** Sydney Metro work showing recent TBM breakthrough*

Alex Conacher
The *Tunnels and Tunnelling* editor has been with the magazine since 2010



Above: Figure 1, Distribution of motorway projects in Sydney

"The Ashfield Shale is not much fun. You generally have to bring in much heavier ground support, going from active to passive depending on where you are and the amount of cover. What you might be able to do with traditional CT bolts elsewhere you may have to switch to cable bolts. We change our designs and processes for Ashfield Shale.

"There are a couple of fault zones in Sydney, and while these do not run cleanly, they are known and understood and so do not pose a problem."

LOOKING ABROAD

The company is associated with Australia, being founded by Australian engineer Sir John Holland in 1949. It changed hands once or twice throughout the years; most significantly it was recently acquired by the China Communications Construction Company (CCCC), a majority state-owned construction giant worth close to USD 30bn and operates in over 100 countries. In 2015 *Tunnels and Tunnelling* reported on a November 2014 joint KPMG-University of Sydney report on Chinese investment that was based off a survey of Chinese investors, and concluded that although they are drawn to Australia as a natural and historical trading partner, they feel limited by a lack of integration into Australia's public and private sector. Australia is an interesting proving ground for these investors. Integration into Australia's marketplace could set them up for success further afield.

As for John Holland, aside from what the rest of the industry probably assumes is some decent financial security, one of the most immediate changes for the company the opening of a Singapore regional office with a country manager – John Anderson – with a view to staking its claim to the upcoming work there, and also to manage work it has already won.

According to Muley, although this was the plan anyway, it happened quicker with CCCC investment. "It was strategic for us to go when we were thinking about it back in 2011, because the growth plans involved a doubling of the railway network there by 2030 – around 176km of tunnelling. On Downtown Line Stage 3 we picked up Contract C935, then on the Thompson East Coast Line we picked up Contracts T208 and T309. Australia was quiet at the time and Singapore had this pipeline. The company works in seven countries in the region, but Singapore is the focus. The Deep Tunnel Sewer System Phase 2 which involves 100km of tunnels is currently out tender."

With the new backing of CCCC, John Holland is contemplating work further abroad, where it can help. The parent company has around 14 design studios and four specialist BIM studios, so management is trying to work out how to share information and help cooperation. However, the pipeline of work in Australia is such that there is plenty to be getting on with domestically.

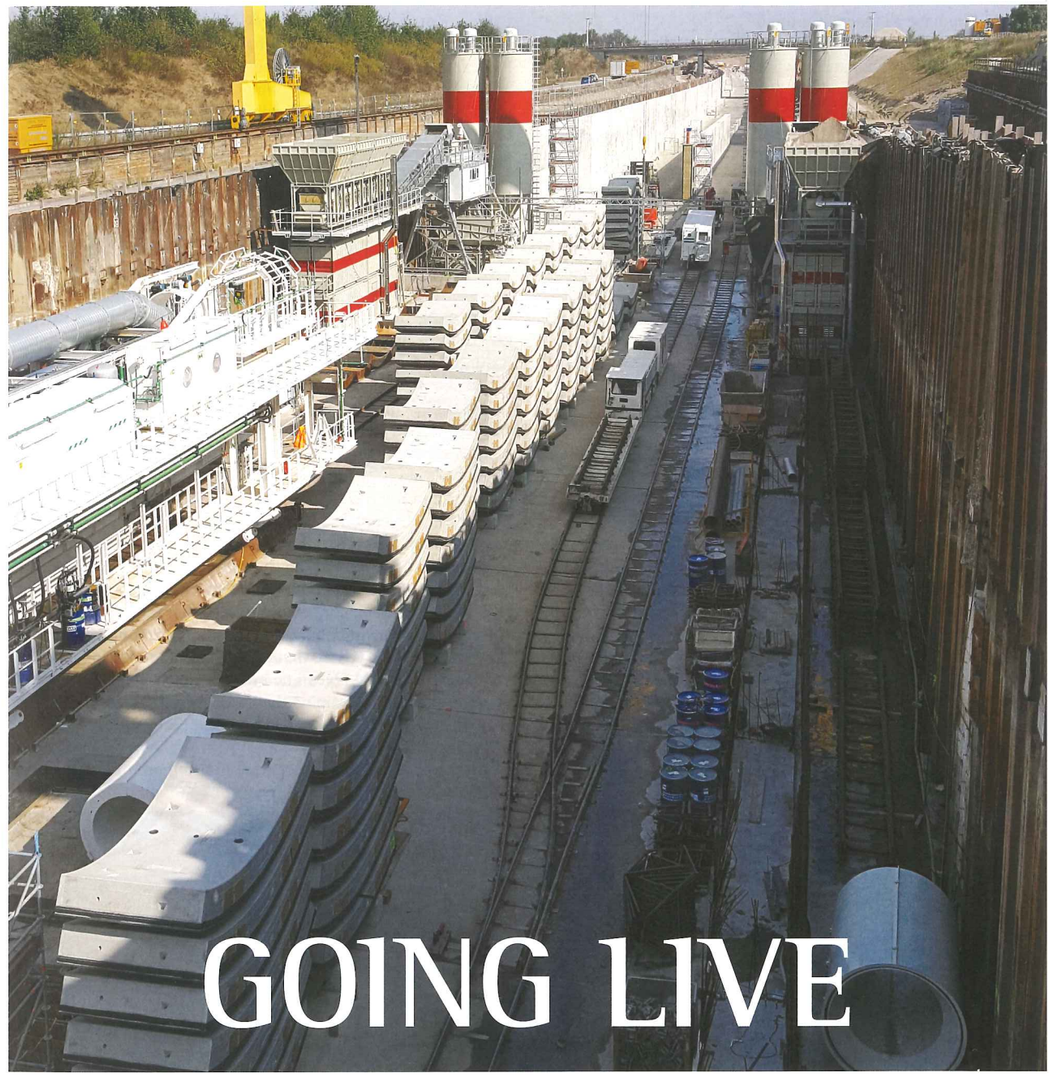
FINAL THOUGHTS

Muley reiterates that the underground construction industry has never had it so good in Australia, adding: "Tunnelling is often in a unique position, working across all sectors: road, rail, water, power and so on.

We are seeing it as a growth area of engineering as more and more infrastructure is driven underground as a preferred option, be it the road tunnels and some rail we are seeing in Australia, or the full cable tunnel system being installed in Singapore. There is less of an appetite for above-ground infrastructure, so we are in a good position in terms of our market

***Bottom left:** Contract T208, Construction of Springleaf Station and Tunnels for TEL in Singapore*

***Bottom right:** Rob Muley of John Holland*



GOING LIVE

EXPANDING THE KARLSRUHE–BASEL rail corridor from two lines to four is a challenging proposition but as a key trans-European rail corridor it is a necessary one. The line forms part of the vital trade route from Rotterdam in The Netherlands down to Genoa in Italy and adding two new lines will allow separation of freight and passenger traffic offering significant benefits to both.

One of the most difficult sections of the project is construction of the Rastatt Tunnel where two, about 4km single bores are required to take the new rail lines beneath the Rhine Valley Railway and the Federbach conservation area. Not only is the ground saturated and soil conditions variable, the tunnel is relatively shallow with the overburden ranging from just 3m

Above: The TBMS are moving from north to south to create the two 4km-long tunnels

Tunnellers must advance through a ring of frozen ground protecting a live railway in order to build the Rastatt Tunnel and create vital new capacity along this crucial European transport corridor

Bernadette Ballantyne
Bernadette is a longstanding regular contributor to *Tunnels and Tunelling*

to 19m. "We have all kinds of ground engineering methods like sheet pile walls and diaphragm walls, bored pile walls, jet grouting, micro-piles, underwater concrete and ground freezing," says Jörg Steppuhn, technical and contract manager for the Ed Züblin/Hochtief joint venture Tunnel Rastatt.

Among this selection of ground stabilisation solutions is an approach that has never been undertaken before, freezing the outer circumferences of the tunnel bores beneath the railway before ploughing through them with the two 10.97m diameter Herrenknecht Mixshield TBMs. "Crossing the Rheintalbahn [Rhine Valley Railway track] it is foreseen to have a ground freezing ring," says Martin Geiger, TBM manager for Züblin. "To produce it two shafts are located at either side of the tracks at a distance of approximately 200m and we have started to drill from that shaft 100m in either direction."

On site the team are in the process of driving the pipes that will later be frozen. "We are drilling the freeze pipes here," says Sören Henke, site manager for the ground freezing and other ground engineering works, pointing at the 30m-deep concrete shaft where a ring of 42 drill pipes are being pushed through the ground using horizontal directional drilling. Placed at approximately 950mm centres and 100m long, the pipes will freeze a 2m thick-band around the tunnel and most significantly ensure that the existing railway, which is only approximately 5m above the tunnel crown, is not affected by the passage of the machines. Crucially the railway line is not allowed to close at any time so prevention of settlement is the biggest priority. "It is the most important challenge for the whole project. The overburden is 4-5m and the railway must remain open," says Geiger.

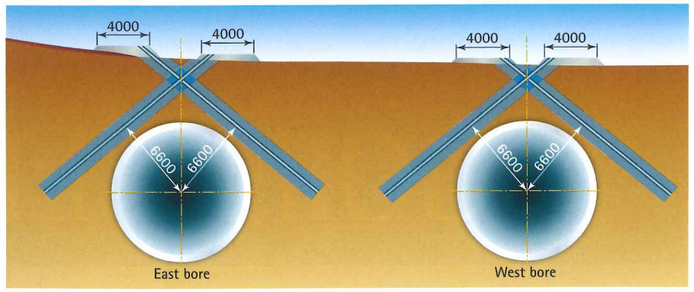
In fact so cautious is the approach by project client Deutsche Bahn (DB) that as *Tunnels & Tunnelling* visited the site the HDD rigs were paused as additional monitoring equipment was installed to ensure that this method does not cause any unacceptable movement. "We are waiting to continue as we expect some influence on the tracks from the drilling so we are waiting for the railway to bring a tamping machine in to repair the track if needed. It's a precaution," says Geiger emphasising that there has been no damage to the tracks to date.

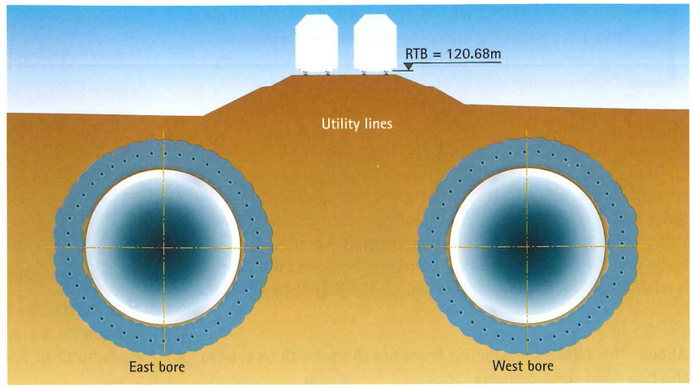
The decision to use the TBM for such a shallow section was a method recommended by the contractor. "Originally it was foreseen to stop the TBMs and do traditional tunnelling with excavators in the frozen ground but we suggested a technical innovation - to continue with the TBM through the ice, which saved money," says Steppuhn. This section, which is located at the very end of the tunnel bore to the south of the line, will then involve construction of cut and cover tunnel after the retrieval of the TBM, connecting to a trough section which is already under construction. Naturally a huge amount of work was undertaken to ensure that this technical innovation would be possible. Thermal and static investigations were conducted by the joint venture to examine the behaviour of the freeze zone. It is crucial that the frozen area remains watertight and that there is no thawing caused by release of thermal energy by the TBMs, or just as importantly that the TBM does not itself become frozen as it passes through the ice. Engineers have devised a range of measures to ensure that this doesn't happen including reducing the amount of suspension in circulation and using aggregates that are less sensitive to temperature changes. "In the planning phase we even had considered a TBM standstill in the frozen ground to be on the safe side," says Markus Heimburger, the project manager for Herrenknecht.

The frozen rings are not the only area where cold temperatures are required to protect the ground. At the start of the tunnel to the north of the site, the cover is again very shallow at less than 5m. To prevent blow out and protect the Federbach conservation area a frozen roof structure was created above the tunnel using an array of 770 freeze pipes drilled, on average, 17m deep into the ground above the tube creating a triangle shaped roof along 190m above the east and 290m above the west section of the bore. "We cannot do a normal tunnel drive with the support pressure at the cutter head because we don't have enough ground above the tube, that means we have to use that construction to anchor the ground above the tube back to the deeper soil," explains Geiger. It also means that the cutterhead can

*Below: **Figure 1, Freezing beneath Federbach. A total of 770 pipes use frozen brine to strengthen the ground and prevent blow out and protect the Federbach. The triangle shaped roof runs 190m above the east and 290m above the west section of the bore***

*Bottom: **Figure 2, Protecting the Rheintalbahn. The pipes will freeze a 2m thick band around the tunnel and ensure that the existing railway 5m above the tunnel crown, is not affected by the passage of the machines***



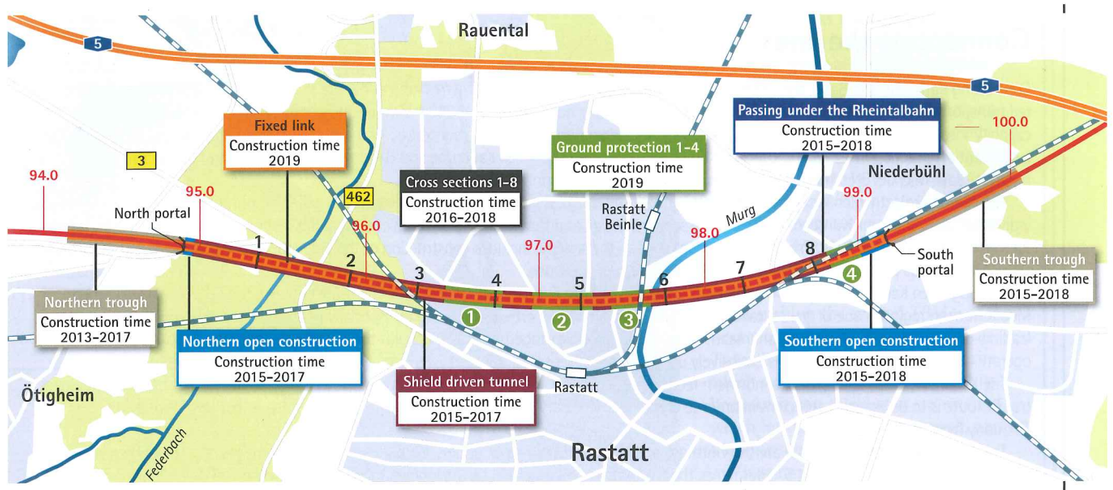


Vital statistics

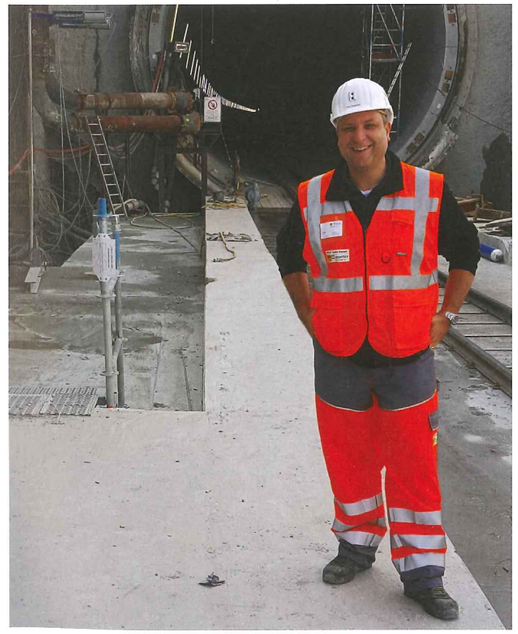
Tunnel bore: 3,890m + 4,030m
Diameter: 10.97m
Internal diameter: 9.6m
Excavation volume: 750,000 million cubic metres. (roughly 1.4M metric tons)
Concrete Trough and Cut and cover tunnels: north l = 800m / south l = 895m
People on site: more than 100
Contract value: EUR 312M (USD 330M) for the Ed Züblin AG/Hochtief Solutions AG joint venture Tunnel Rastatt.
TMB cost: EUR 36M (USD 38M)

GROUND FREEZING:
Federbach (roof): 22,000m³ (190 m + 290m)
Rheintalbahn undercrossing (ring): 27,600m³ (2 x 200 m)

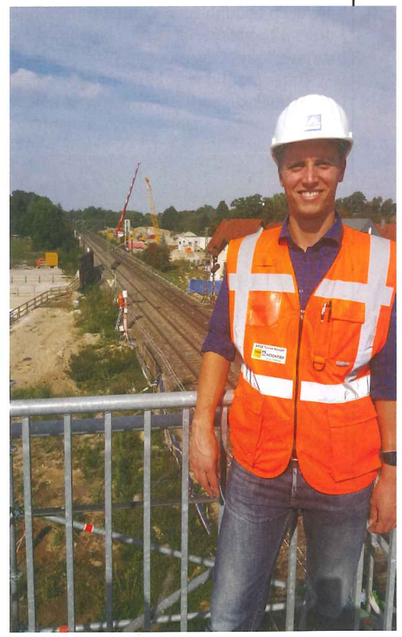
MATERIALS:
56,0000m³ of supporting walls of the construction pits/groundwater basins for the trough and cut&cover sections
123,000m³ of in-situ concrete,
33,000m³ of underwater concrete and
17,000t of reinforcement



*Above: **Figure 3, Route map***



*Left: **Jörg Steppuhn, technical and contract manager for the tunnelling contractor the Ed Züblin AG/ Hochtief Solutions AG joint venture Tunnel Rastatt***



*Right: **Sören Henke, site manager for the ground freezing and other ground engineering works Ed Züblin AG/Hochtief Solutions AG joint venture Tunnel Rastatt***

Connecting the lines

Connecting Karlsruhe and Basel, the Rheintalbahn or Rhine Valley Line is 182 kilometres long and more than 150 years old. Critically important to rail transport, it is used for both regional and international connections. Today over 250 trains use the line daily and it has reached the limits of its capacity meaning that the original two-track line will be extended throughout to four tracks. "This will considerably increase its capacity and bring a substantial reduction in travel and transport times. The travel time between Karlsruhe and Basel will be reduced by half an hour to just 69 minutes," says Michael Bressmer, spokesperson for client Deutsche Bahn.

The overall project which includes the Rastatt Tunnel is made up of a total of nine line sections. For planning purposes these were divided into individual "planning approval sections" and these sections are all at different stages of completion and the first construction project for Achern Railway Station began in 1987. Previous tunnelling work on the scheme includes construction of the Katzenbergtunnel which was completed in December 2012 as part of the 17.6km long southern section of the works.

The upgraded Karlsruhe–Basel railway line sits at the core of the European goods corridor. The route between the Dutch harbours and the Mediterranean region is one of the so-called Trans-European Networks, arteries classified as especially important by the European Union. With leading-edge technology, these lines are meant to bring Europe closer together. In 2007 one of the most modern lines worldwide went into operation in the Netherlands, which is exclusively used for goods transport. This "Betuweroute" extends from Rotterdam to the German border.

The Karlsruhe–Basel line forms the northern feed to the AlpTransit, also known as the New Railway Link through the Alps (NRLA). This alpine transit route is to be especially efficient in order to create the necessary conditions to shift heavy-goods transport between Switzerland and Germany from road to rail.

The central projects of the NRLA are the Gotthard and the Lötschberg base tunnels. With a length of 34 kilometres, the Lötschberg base tunnel was opened back in June 2007. At 57 kilometres, the Gotthard base tunnel will be the longest railway tunnel in the world. The Gotthard line is continued to the south by the 16-kilometre Ceneri base tunnel, construction of which began in 2006.

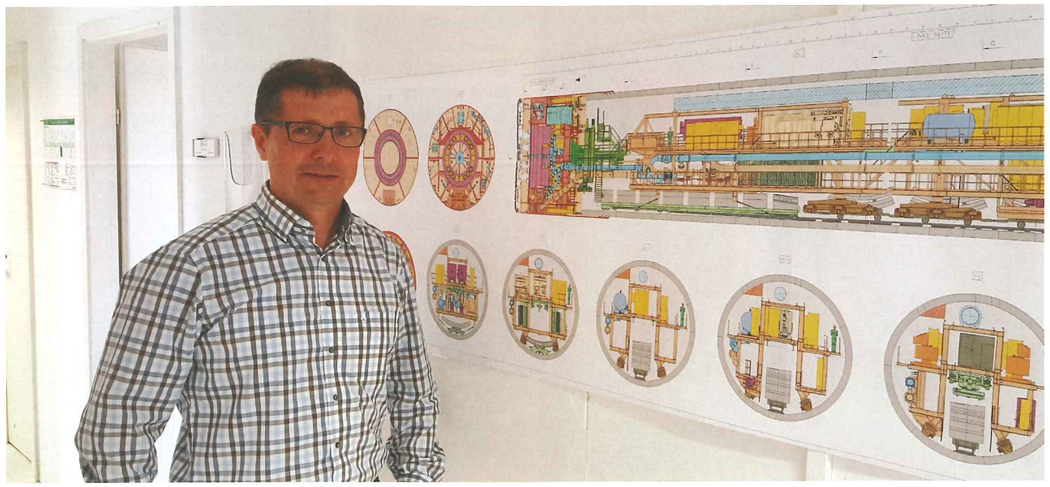
Efficient operation also has to be guaranteed on the German side – this is one of the main reasons for the new and upgraded line from Karlsruhe to Basel.

only be inspected in this area by dropping the bentonite level by one-third the bore diameter of the TBM as the compressed air pressure used to replace the bentonite could otherwise lead to a blowout. So an inspection was carried out before the first machine reached the frozen roof.

This first TBM has undertaken more than 1km of tunnelling with the second about to get underway as *Tunnels & Tunnelling* visited the project. "Now we are deep enough for a normal tunnel drive without special construction at the surface," says Geiger.

Other ground freezing measures will be used to support construction of the eight cross passages and protect them from the potential for water ingress due to the high water level at the site. Located every 500m traditional SCL shotcrete lining methods are being used for these connecting tunnels.

But first the team must complete the main bore and below ground a seven-person team led by the contracting joint venture's project engineer Ursula Wegener, is making good progress in the quaternary gravels heading into the soft tertiary layer with quaternary rocks and cohesive covering layers of sandy clays and silts. The TBM operator is feeling his way forward at around 20mm/min applying 42,000kN of driving force at the face. Pumps are moving bentonite to the face at a flow rate of around 2500m³/hour and each 2m advance takes around two hours. The Mixshield machine has a standard cutting head with an opening ratio of around 30 per cent. "It is all about getting the right balance," observes Wegener, with the multitude of



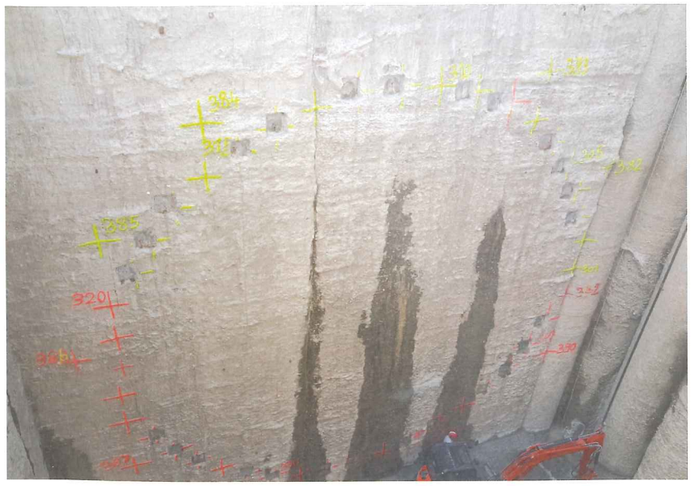
Below: ***Martin Geiger, TBM manager for Züblin***

control screens that tell her and the TBM operator everything about the machine and its relationship with the ground.

One of the challenges that the underground team are facing is the abrasiveness of the ground which means that more inspections and more cutting tools have been required than was originally expected. "The abrasiveness of the ground is influencing the tunnel drive more than expected, we have been surprised at the amount of wear. When we are running we do 16-18m per day but we are having to change cutter tools more often which means standing still for two to four days and this brings the average down," says Geiger.

For Wegener the abrasive ground also means that her team must inspect the pumping equipment frequently to check for wear on the steel pipes. "Every week we inspect the slurry pipes and we can turn the pipes or place on extra steel if the wear is too much," says Wegener. Using electromagnetic measurement the team checks that the pipe thickness remains greater than 4mm as maintaining the slurry removal is clearly a critical activity.

Above: ***The contracting joint venture's project engineer Ursula Wegener***



Below: ***One of the project's rings***

Each tunnel ring consists of seven 11.5t segments which are manufactured in Bavaria by Max Bögl and transported by rail to Rastatt station before lorries transport two at a time to the site. The current delivery rate is three trains per week and 23 rings per train. "We are really pleased with the lining quality," notes Steppuhn.

Launching the second TBM was the next major task for the contractor as *Tunnels & Tunnelling* visited the site, which was planning to implement its bespoke flying shield start up method which has been used on Crossrail, and the Cologne and Hamburg metros.

"It means pulling the TBM forward instead of pushing it. The main principle of this kind of TBM launch is that the abutment for the TBM's driving jacks, unlike as the classic thrust frame, automatically advances towards the soft eye wall. This will be done by 24 hollow piston jacks and tension rods which connect the abutment with vertical steel girders at the soft eye wall. Those vertical steel girders then transfer the forces to a concrete beam above the portal and to the concrete slab," says Geiger.

The second TBM is purposely launched several months behind the first. As the bores are between 17 and 26m apart there is the potential for one bore to affect the other so a staggered start is required.

Unusually for the TBM manufacturer Herrenknecht, which delivers its machines all over the world, the project is conveniently close to their Schwanau headquarters. Development of the two 10.97m machines took around one year.

"For both sides it is an advantage the location being so close. It is easier to provide good and fast support for the job site, and we can bring people to see what we are doing. It is also an emotional thing for people at Herrenknecht – like having it in the family. People are proud of our TBM working so near," says Heimburger.

Despite the abrasive ground the team is maintaining good progress on the project and is well prepared for the challenge ahead, where the machines will bore through frozen earth just 5m below the existing live railway. Completion of the tunnel bore is scheduled for September with separate contracts for fit out, tracks and M&E works underway until December 2018 at which point the crucial link in Germany's Trans-European Network will be complete

THE BOG STANDARD

Tunnels and Tunnelling speaks with engineers working on the East Renfrewshire water main project as Scottish Water aims to improve drinking water for 200,000 people

AS WELL AS THE more famous Shieldhall project in nearby Glasgow where engineers are constructing Scotland's largest wastewater tunnel, Scottish Water is also investing heavily in the drinking water network in the Ayrshire and East Renfrewshire regions of Scotland. While the East Renfrewshire water main project does not have the impressive dimensions of Shieldhall, which boasts a 4.7m diameter and 5km length, it has its own challenges.

Below: Much of the route involved weak ground
ALL PHOTOS: SNS PHOTOGRAPHY

The project is part of a GBP 120M (USD 150M) investment into the network.

The first phase involves the construction of a 21km water main, which was designed and built by the Caledonia Water Alliance, a joint venture of Morrison Utilities and Aecom. The steel pipe was 1,000mm in diameter and supplied by FP McCann.

The choice for steel pipe led to one challenge as the location of the Amlaird Water Treatment Works, combined with the need to gravity feed the facility, means that a 4km section of the pipe needs to travel through a peat bog called Fenwick Moor.

Stewart Davis, Scottish Water's programme manager, explained: "The geological make- up of the area is

predominantly peat bog, which is between 500mm and six metres deep. The peat, by its nature, is a soft and wet material which does not have the competent geological structure to support a steel pipe which weighs four tonnes per 13m length when full of water.

"So our engineering solution was to excavate to competent clay type soil and then fill the ground back up again with imported stone to provide a competent structure to lay the pipe on."

The stone quantity varied in accordance with peat depth but estimated to be around 1,000t.

The peat bog has presented the contractors with logistical issues in terms of access across this area coupled with the selection and availability of specialist plant such as wide tracked low ground pressure excavators and long reach excavators. Peat was replaced after completion.

All equipment and materials required to construct the pipeline across this peat bog has had to be transported there via a purpose-built floating stone and timber mat road, which CWA constructed over the first few months of the project.

Sean Lavin, the CWA project manager said: "The floating road was made up of tensar geogrid with a teram membrane attached. The stone was 8"-4" graded, dust free, the timber mats were used where better competent sub structure existed such as clay material, the mats are made of hard wood timber and are 5m-long by 1m-wide and are 100mm-thick. We had no problem getting machinery in to construct it. The road can take up to 40 tonne loads without sinking."

RAIL CROSSING

An additional challenge was pipe installation under an active railway line. For this section ground investigations were undertaken by ESG and a remote controlled, laser-guided Herrenknecht slurry TBM drove through a mixed face of clay and rock. Settlements were kept beneath 25mm and the line did not need to be closed.

FINAL THOUGHTS

Lavin concluded: "The entire job has logistical challenges be it ground conditions such as hard rock/height restrictions/weight restrictions/working hour restrictions/Water supply for testing only available at the two extreme ends of the pipeline."

When asked if there was a previous project this work was based on, Lavin added: "It was the experience of construction team. Key members of the team have decades of welded steel pipeline experience in every type of environment but not previously with Scottish Water.

Scottish Water's Davis added: "The work on the peatland on Fenwick Moor, and under the railway line have presented us with major engineering challenges but we have met or are meeting

Top and centre: Herrenknecht machine preparing to pass under the rail line

Above: The pipe is buried next to the temporary road

those challenges head-on and progressing well with this important first phase of the overall project."

Construction on the project ran from January to December 2016. Tunnelling began on 4 April and completed on 25 August. The whole project should be complete in March 2017. The other sections of new mains will be a section of about 13 miles from the Fenwick Waterside area to Dundonald in South Ayrshire and a section of about six miles from the Pollok area to a reservoir storage tank in the south of Glasgow

UTILITY PLACEMENT

Tunnels and Tunnelling takes a trip to Herrenknecht in Schwanau and meets Michael Lubberger, senior product manager for pipelines to find out more about developments in the utility placement range

Above: Michael Lubberger

IT IS HARD NOT to be spellbound by the 15.87m diameter TBM being disassembled at the Herrenknecht headquarters in Schwanau, Germany. Technical acceptance of the machine, the largest ever built at the factory, took place at the end of August and now, in late September, an enormous white, rail-mounted gantry crane sits above the 4,800t earth pressure balance machine, systematically removing components as it is prepared for transportation to its ultimate destination in

Bernadette Ballantyne
Bernadette is a longstanding regular contributor to *Tunnels and Tunelling*

Italy. Herrenknecht technicians seem to blend in to the pipework as they carefully deconstruct the TBM, which has been purchased by Italian contractor Pavimental S.p.A to build the 7.5km Santa Lucia tunnel through the Apennines as part of the renewal of the Autostrada A1.

The incredible scale of the machine makes it hard to imagine a bigger one. But the Santa Lucia TBM has a larger cousin. In May 2015 a 17.6m Mixshield began boring the Tuen Mun-Chek Lap Kok Link in Hong Kong for the Dragages-Bouygues joint venture on the first section of a 5km tunnel connecting Hong-Kong's airport to the mainland.

As fascinating as it is to learn about the development of Herrenknecht's largest machines and see Europe's largest TBM being taken apart, *Tunnels & Tunnelling* has another item on its agenda focussing on the opposite end of the tunnel boring size spectrum. "We have been focussing on downsizing, although the market goes both ways of course," says Michael Lubberger, senior product manager for pipelines in oil and gas at Herrenknecht. He points to one of the most recent developments, the company's smallest ever horizontal directional drilling (HDD) rig. Existing models have traditionally been at the maxi or mega range with a pull force of up to 6,000kN but the latest model is a smaller 80t machine. The new HK 80 CK has a crawler base (C) and the K denotes its "Kompact" size. It uses a 20ft (6.1m) drill pipe compared to the standard 32ft (9.8m) and a number of measures have been implemented to ensure that the rig has a smaller footprint and lower transportation requirements. For example the fluid pump is small enough to be fitted on board at the factory, and the use of a Siemens PLC system for steering control has significantly reduced the number of electrical components.

Its compact size makes it ideal for pipe placement in urban areas says Lubberger. "It takes around half a day to set up and saves a lot on transport costs. The first machine will go to a site in the Pyrenees at the end of October," he says noting that expected installations would be HDPE pipes and power cables and key markets are Europe and the US.

Development and design of the new machine took around six months and was a response to growing demand in the market, as was the development of a new range of HDD down hole tools also released this year. "We saw that there was a need for better hole opening and cuttings transportation," says Lubberger pointing to a steel barrel-shaped tool sitting in the yard. "This is just back from its first job. We supplied it to the contractor as we wanted to see how it performed on a real worksite. It was used in hard limestone and flint so it was an abrasive environment."

The new tool is the down hole jet pump, which has been specifically designed to increase the efficiency of the boring process by improving the removal of excavated materials and therefore reduce the risk of what is known on site as "frac-out". This is where the bentonite-based drilling fluid pumped in to maintain the hole and remove excavated material, builds up in the bore creating an over-pressurised environment. If the overburden above the bore is less than the pressure generated by the fluid in the hole then the bentonite suspension will inevitably seek to restore the balance by finding an alternative path, which is likely to mean a blow out at the surface. As well as removing the potential for pressure build up during excavation, the new down hole jet pump also maintains a very clean bore hole, which is designed to make subsequent pipe placement faster.

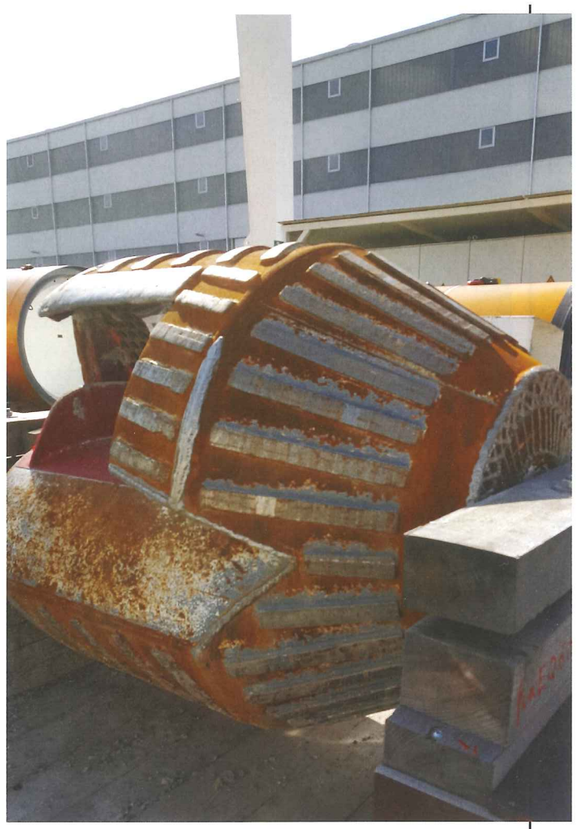
To date the traditional method of cleaning an HDD run has been using a barrel reamer, which is pulled through the borehole after the initial path has been opened with the pilot bore and a cutter head has made several passes through the bore to open it up to its final required diameter (see box). "The down hole jet pump works differently. Instead of pumping fluid through the borehole it acts as a down hole vacuum cleaner," says Lubberger explaining that the rotation of the barrel and its unique shape causes cuttings to fall into the pump where they are then pulled inside the drill string and pumped out towards the mud cleaning equipment on the surface. It comes in a range of sizes between 20 and 70 inches. "The advantage is obviously that the cuttings can be much larger and the borehole will not be pressurized as you are not pushing mud through it anymore," says Lubberger.

"With the conventional barrel cleaning run technology cuttings of up to 10mm can be transported if the mud properties are well aligned. But mostly you just get sand out of rock drills, the bigger cuttings will stay at the bottom of the borehole," he says. However the new down hole jet pump can transport cuttings of 35mm.

TESTING TIMES

As Lubberger points out the new jet pump has been tried and tested. In Malmö, Sweden, a Herrenknecht HK150C rig was used for a 260m drive through hard limestone with sections of flint. The contractor BAB Röryryckning AB needed a very clean borehole due to the tight dimensions with only a small annulus between the bored diameter and the 40inch (1m) HDPE pipeline that was to be placed as a protective pipe ahead of the final steel district heating pipework. Lubberger says that the contractor was surprised by the volume and diameter of the material that emerged. "Cuttings of up to 50mm in length were discharged. Larger cuttings had been crushed by the down hole jet pump into smaller pieces or pushed into softer sections of the borehole," he says noting that the tool can also be set to flushing mode when crossing softer parts, which it encountered on both sides of the crossing. This avoids the grid of the pump clogging up," he says.

Another innovation is that the down hole jet pump can be used directly behind a newly-developed cutter called the "full face hole opener". The cutter reams from the initial pilot hole to the final diameter in a single step, which also has the advantage of maintaining the bore through the centre of the pilot hole. One of the challenges for HDD operators making multiple passes to gradually increase a pilot bore diameter, is maintaining the centre line of a bore as

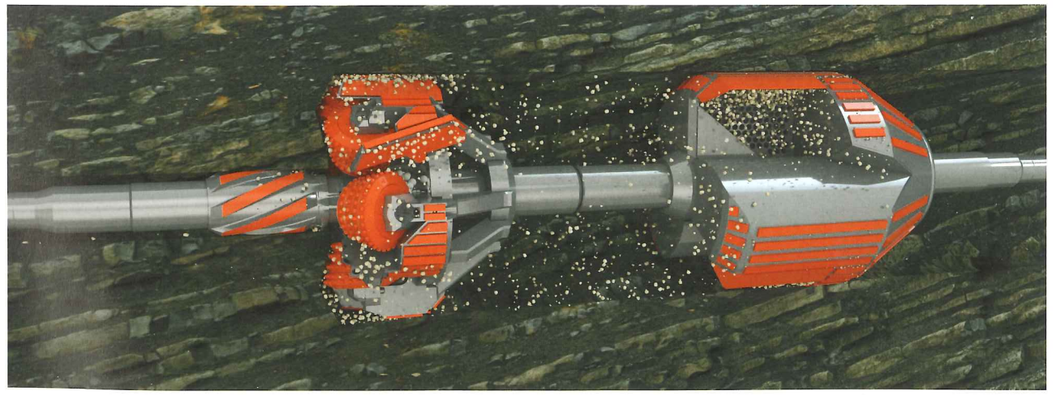


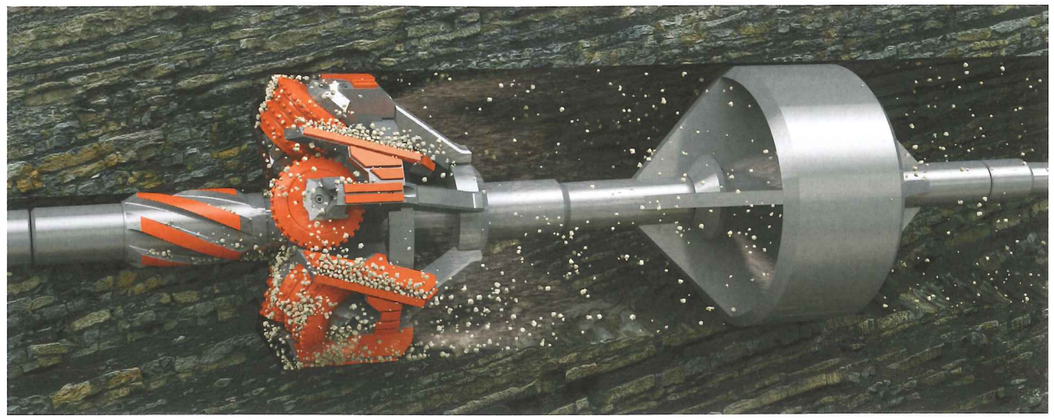
Above: A jet pump

Below: An illustration of the Hole Opener

Above: The Santa Lucia TBM in Schwanau

Below: A horizontal directional drilling rig





an offset often develops between the axis of the drill string and the axis of the reamer heads. According to Herrenknecht its single pass full face hole opener reduces the tilting of the reaming head and therefore the potential for damaging bending loads on the drill rod.

Designed for rock the hole opener has larger bearings than traditional cutting tools allowing it to withstand up to twice as much pressure and therefore allowing greater penetration and it can cut through rock with a hardness of up to 350MPa. Herrenknecht points out that one of the biggest advantages of the hole opener is that by using a single cutting tool over a single pass major cost and time savings are gained.

Top: An illustration of the down hole with full face

Above: Herrenknecht's full face hole opener in Kansas

The full face hole opener head itself can house a range of roller cutters including milled tooth (MT) bits in softer rock and tungsten carbide inserts (TCI) in harder ground. Both have been put to the test on the Flanagan South Pipeline project in the US where contractor Laney Directional Drilling of Houston, Texas, working for main contractor The Enbridge Company, used the HDD method with the full face hole opener for two river crossings. In the first location, near Independence in Kansas, the 36 inch (DN900) steel petroleum pipeline had to cross 536m beneath the Verdigris River. Boreholes dug at 40m depths either side of the river revealed alternating, thin, horizontal shale and limestone layers with varying strengths up to a maximum of 108 MPa. The alternating layers made it challenging to maintain the proper line and grade of the borehole for which the pilot bore was created with a 12.25in TCI Tricone drill bit in combination with a drill motor. After the pilot hole was drilled, reaming to the ultimate 48in (1219 mm) diameter was carried out by the 48in full face hole opener in just one step. It was equipped with a set of TCI roller cutters designed for very hard formations along with a 47in centring device, which was attached behind the hole opener and increased the concentricity of the reamer head.

Installation required low pull forces and was carried out without complications. The roller cutters were used for a total of 197 hours and were sent off the Herrenknecht's Seattle facility for inspection. The body structure of the roller cutters and the tungsten carbide inserts showed little wear so the roller cutters were fitted with new seals and bearings to be on the safe side.

Horizontal directional drilling – a mainstay method for utilities

HDD uses a rig at ground level to launch a pilot bore which drills an arc along a planned underground trajectory, usually sweeping beneath an obstruction such as a road, river or railway. A bentonite suspension is pumped to jets in the drill head and in soft ground this high pressure fluid will excavate the face and then carry cuttings back to the surface. In rock a mechanical cutting tool is needed to excavate the bore. Following completion of the pilot bore the hole must be expanded and so a reamer or fly cutter is then connected to the drill rod at the exit hole, which is then pulled back towards the rig, opening up the bore. Again a bentonite suspension is used to support excavation and carry out the cuttings. Several passes of various cutter heads may be required depending on the required diameter. Once the required dimension is achieved the final pipeline is then connected to the back of a barrel reamer which cleans the hole ahead of its placement. Herrenknecht's HDD rigs are used for pipes of diameters between 0.1m and 2m.

The lack of need for launch pits and increasing productivity of machines has increased the popularity of the method which has been widely used since the 1970s and 1980s.

The reamer body structure also showed relatively little wear, and only in the area of the replaceable front centraliser was hard facing re-welded for the next borehole, which would also prolong the life of the front centraliser.

CROSSING RIVERS

Further south the same pipeline needed to cross under the Arkansas River in Cleveland, Oklahoma. In this location the ground conditions were mainly sandstone with layers of shale and limestone. The rock strength was around 55MPa and the layers were moderately broken with an RQD index of 50-60 meaning that there was a moderate risk of an unstable borehole because rocks from the borehole wall may fall into the invert. The presence of shale layers increased the risk of clogging the reamer head with material. One special feature of this borehole is that the reception side is about 130ft (40m) higher than the launch side. This means that for over a distance of about 755ft (230m) the borehole is dry. The horizontal layering of the different formations meant that the long horizontal part of the borehole could be run through the more stable sandstone as compared to the first project. With the better stability, the sandstone seemed the best layer to drill in. However, it was feared that the abrasiveness of the sandstone due to its high quartz content could cause high wear on the roller cutters and reamer body.

After the pilot hole was completed Laney's own 3000kN HDD drilling rig was set up on the higher side and the 48in (1.2m) full face hole opener connected to the drill string on the lower side. With the lower compressive strengths of the sandstone and limestone the decision was taken to use a set of milled tooth (MT) cutters on the hole opener, as the greater tooth protrusion of MT cutters of around three times more than tungsten carbide insert protrusion of the TCI cutters, means that in softer ground it should make faster progress, theoretically allowing more than two and a half times higher penetration per revolution.

Again the installation went smoothly and despite the abrasive section of sandstone, the wear on the body structure of the reamer head was only moderate. After the second project, however, the front and rear centring units needed to be replaced. The MT cutter bodies were worn out and could no longer be used for another project.

The river undercrossing has shown that the MT roller cutters work well and that the reamer head runs very concentrically down hole. It has also been found that the nozzles in the reamer head have an important role to play in reducing the clogging of the reamer head as the configuration of the 20 different nozzles was altered as the bore passed through sticky shale sections.

Above: The full face hole opener in Oklaho

TOOLING UP

That the new tools are performing well is good news for Herrenknecht, which has given its HDD range a special focus over the past 18 months acknowledging the massive global requirements for renewing and installing new utilities.

Other utility placement methods developed by the firm include the Direct Pipe system which combines microtunnelling and its Pipe Thruster technology to place pipes of between 0.8m and 1.5m; its well known AVN machines used for pipejacking diameters of 0.4m to 4.2m; its auger boring machines and of course the full range of TBMs, which have been designed for tunnels of between 1.5m (Single Shield) up to potentially 19m (Mixshield and Multi-mode).

Although it is yet to be built designs for a 19m TBM are complete and development continues at the cutting edge of large diameter tunnelling reinforcing Lubberger's point: development is indeed happening at both the small and large diameter ends of Herrenknecht's tunnelling world

Below: An HDD pump

Modelling Soil Structure Interaction during Tunnel Excavation

NAFEMS seminar

Co-organised by British Tunnelling Society

23rd February 2017
Coventry

This seminar will focus on numerical modelling of the complex interaction between soil and structure during tunnel excavation. This is a major talking point currently, with over 26 miles of tunnels being built under the UK's capital city as part of Crossrail and numerous London Underground Station Upgrade projects. Ensuring that the tunnels are correctly designed is essential to ensure the safety of those involved in the tunnelling operation as well as ensuring that life above ground carries on without interruption.

The event will focus on modelling of the soil-structure interaction behaviour in tunnel construction, with an emphasis on sprayed concrete lining. This seminar will provide guidance on the following topics.

1. *Time dependent nature of sprayed concrete material properties*
2. *Variability in material properties*
3. *How to reduce unnecessary conservatism when designing a sprayed concrete tunnel lining*
4. *How to ensure your design is code compliant.*

Other modelling issues associated with tunnel construction such as compensation grouting and building damage will also be discussed and there will be presentations from leading experts from Mott MacDonald, UnPS, Keller Holding GmbH, Oxford University, etc.

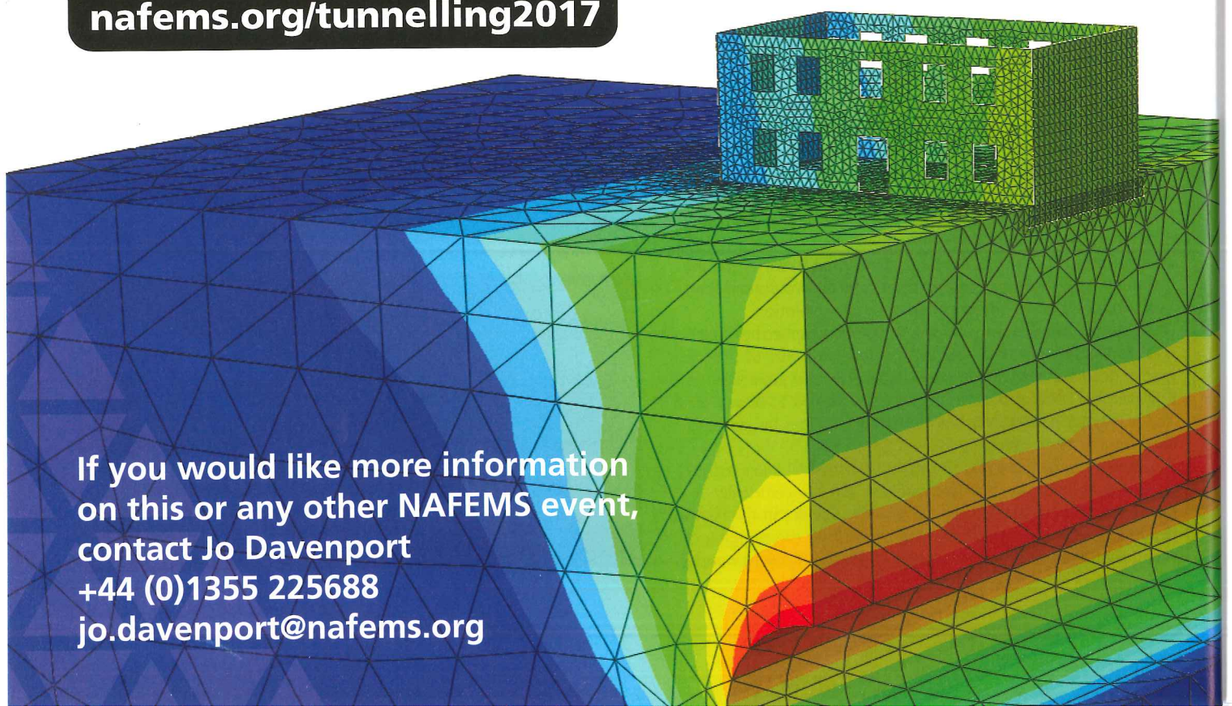
We are also pleased to have Professor Helmut F. Schweiger from, Graz University of Technology giving a keynote presentation.

Dr Andrew Mar from UnPS, author of the upcoming NAFEMS publication entitled 'Modelling Sprayed Concrete Lined Tunnelling' will also be presenting on his book, with a discount available on purchase of the publication exclusively to those who attend.

In addition to addressing the issues relating to modelling tunnel excavation, a number of case studies will be presented during the seminar. The day will be concluded with a discussion chaired by Professor David Potts on the different methods of representing sprayed concrete that are currently used in industry.

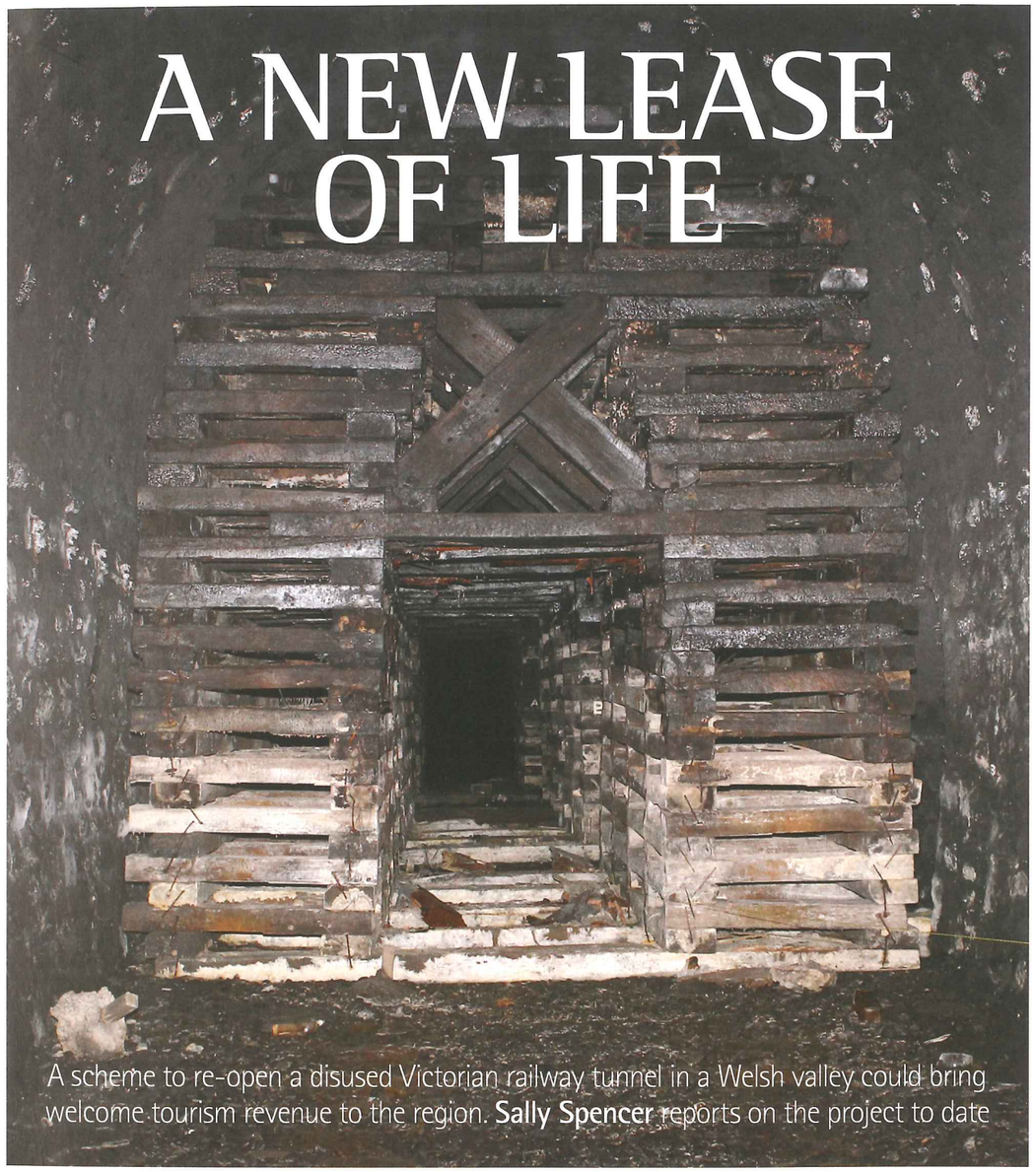
Who Should Attend?
We hope to see the seminar attract interest from tunnelling and geotechnical engineers, designers, FE/FD modellers, project managers and constructors who want to learn more about the latest developments in modelling the tunnel excavation process.

nafems.org/tunnelling2017



If you would like more information on this or any other NAFEMS event, contact Jo Davenport
+44 (0)1355 225688
jo.davenport@nafems.org

A NEW LEASE OF LIFE



A scheme to re-open a disused Victorian railway tunnel in a Welsh valley could bring welcome tourism revenue to the region. **Sally Spencer** reports on the project to date

WHEN STEVE MACKEY WAS about 13 years old, a couple of his friends dangled him by a rope over the portal of a disused railway tunnel by his ankles, 14m above the track bed. This was not to scare the living daylights out of him but was so he could re-paint the commemorative portal stone. When he did so, he added the words "please open me" and his signature to the side of the stone.

That was in the late 1960s. Fast forward to a country walk in 2014 when in a bizarre twist of fate Mackey stumbled across the portal stone, covered in brambles, lost and all but forgotten. Within a few days he had organised its removal and restoration

***Above:** A timber 'cwg' has been erected to prevent a tunnel collapse*

Sally Spencer
Sally joined the *Tunnels and Tunnelling* team as a contributing editor last year

at a local stonemason and the stone is now on display at nearby Treherbert station.

This sowed the seeds of the Rhondda Tunnel Society (RTS), of which Mackey is chairman, and its campaign to restore and re-open the 3.18km Rhondda Tunnel as a cycle path and walking route.

Campaigners believe that this would create the second longest cycling tunnel in the world, bringing much needed tourism revenue to south Wales.

"The longest cycling tunnel is Snoqualmie in Washington State in the US, which is 3.7km long," Mackey says. "That is closed for half the year because of the weather so, technically, our tunnel would become the longest for six months of the year. I don't know how we market that but we're working on it."

Above: A view of the masonry section of the tunnel

Below: Rubble at the base of the ventilation shaft is probably from a chimney above ground

A precedent exists closer to home in the form of Two Tunnels Greenway, a cycling route in Bath that links to the National Cycle Network. The longer of these two tunnels, Combe Down, features an interactive light and sound installation. The tunnels opened in 2013 and attracted 278,000 visitors in the first year and Mackey would like to see this level of visitor numbers and more exploring the Rhondda Valley.

The Rhondda Valley was the beating heart of the coal mining industry in south Wales.

"There were so many pits in the Rhondda that they were digging the coal out before they could deliver it because they had to take it from the valley down to Cardiff, up to Bridgend and then on to Swansea," Mackey says.

There was a more direct route to Swansea – through a mountain. Enter one SW Yockney, an engineer and protégé of Isambard Kingdom Brunel, who took on the challenge to connect the village of Blaencwm in the Rhondda Valley with the village of Blaengwynfi in the Afan Valley.

Work by the Rhondda and Swansea Bay Railway company took place between 1885-1890, with excavations starting from both ends. When the tunnellers met in the middle of the 3.18km tunnel they were less than 7mm out of true.

At its deepest point the tunnel is almost 305m below ground and features a single 18m-deep ventilation shaft around 96m from its western end. The single line tunnel split into a double track on emerging from either portal.

The tunnel was opened in 1890 by the Railway Inspector of

the day, a Colonel Rich, and transported coal for the next six decades. In the late 1950s it also opened up to passenger transport although, as Mackey says, this was relatively brief and unsuccessful.

The tunnel wasn't without its problems during its operational life. Underground springs meant the tunnel was very wet in places and water had to be channelled away via a drainage system. In addition, subsidence caused by the coal mining above and below the tunnel resulted in the movement of the brick and stone lining and resulted in further water ingress – although this is confined to both ends of the tunnel (92m from the Blaencwm portal and 73m from the Blaengwynfi portal).

Attempts were made to stabilise the structure in the late 1930s by installing arched steel ribs around the tunnel lining but some of these were pushed out of shape as ground movement squeezed the sidewalls in and the arch upwards.

The tunnel closed to rail traffic in 1968 and when the Ministry for Transport decided not to repair it, due to the prohibitive costs (and in line with the British Railway chairman Dr Beeching's swingeing cuts to railway services), the line was permanently closed in 1970. The tunnel then became a playground for the young Mackey, who, in spite of his mother's concerns for his welfare, would sit at its centre and "marvel" at the Victorian brickwork by candlelight.

His fun was curtailed in 1979 when the local authorities filled in the approach cuttings at either end. A series of concrete pipes were built into the infill material at the Blaencwm portal end so that access was still possible for tunnel inspection purposes. Following vandalism of the ground level access hatch, this was plugged with concrete, so no further inspections could take place. However, in 2008 the concrete plug was removed by persons unknown and subsequently replaced with a lockable steel hatch by the British Railways Board (BRB).

Above: Blockwork wall and ventilation shaft at the Blaengwynfi end

Below: The sidewalls and arches of this section of the tunnel are concrete

The BRB was abolished in 2013 and ownership of the tunnel passed to the UK Secretary of State for Transport, who appointed the Historical Railways Estate (formerly known as the Burdensome Estate) to manage it. Historical Railways Estate (HRE) is part of Highways England (formerly the Highways Agency).

"So currently the tunnel is in 'foreign' – i.e., English – ownership," says Mackey. "This precludes the RTS from applying for

grants from Welsh funding agencies to pay for a detailed survey. It urgently needs a letter of intent from the Welsh government to say that a Welsh government body will accept ownership of the tunnel it is to re-open. The transfer of ownership would come with a GBP 60,000 [USD 74,000] dowry."

No detailed surveys have been carried out as yet and up until recently there were no records available of the tunnel's condition since the 1960s. In 2014, as part of the information gathering exercise behind their Tunnels Strategy, HRE decided to carry out a special examination led by structural engineering company Hammond (ECS).

Above: The ventilation shaft is sealed at the top with a steel shutter supported by five beams

Below: The reinforcing steel ribbed section

The survey took place over three days in April 2015 and was not for the faint-hearted or claustrophobic. Engineers accessed the tunnel by being lowered around 10.5m down the inspection shaft near the Blaencwm portal and then crawling through a pipe approximately 0.6m in diameter and 5m long.

HRE engineer Lee Holland, who joined the survey, noted that this eastern end of the tunnel was wet underfoot, with running water entering through the arch and sidewalls at various locations. There was no ponding, however, and water was flowing away via the original track drainage towards the infilled cutting.

The survey also showed that the steel ribs around the arch were in poor condition but didn't appear to be unsafe. The same could not be said for the timber lagging between the ribs and the stonework of the tunnel arch, which were rotting and, in some cases, had fallen away. Small sections of stonework had also fallen from the tunnel crown, although this is thought to have happened as a result of the movement recorded in the 1950s/60s, and may have stabilised.

Moving in the direction of the Blaengwynfi portal, the tunnel was relatively dry. Engineers noted mass concrete in the tunnels, which they presumed had been fixed in front of the original masonry. About half way through the tunnel they saw large recesses built into the sidewalls with the arches here correspondingly wider.

Further in they encountered a timber "cwg" at the point where the tunnel arch was at its most distorted. This structure was made up of two separate lengths of railway sleepers built up into the shape of the tunnel arch with a central opening big

enough for people to walk through. They concluded that this cwg had been constructed to resist any further movement of the tunnel lining and keep the tunnel relatively clear in the event of a collapse. Some of the timber in the cwg had rotted away but the overall structure seemed stable.

The final 100m at the Blaengwynfi end is blocked by a concrete wall and close to this is the aforementioned single ventilation shaft. This is brick-lined and circular and was estimated to be 11m high above the crown of the tunnel arch. The top of this airshaft had been sealed and large volumes of brick rubble – probably from the demolition of a chimney above ground – had been pushed down into the tunnel.

The surveyors concluded that the condition of the tunnel hadn't deteriorated since it was closed to rail traffic in 1968. Coal mining had caused ground movement and since this had stopped, the ground appeared to have settled.

They also reported that the tunnel conditions didn't preclude further similar examinations taking place but that, given the hazards and relative inaccessibility, remote inspections would be preferable.

Mackey's opinion is more enthusiastic.

"I have been in the tunnel four times in the last year and the condition is quite remarkable," he says. "There are places that need attention but with the technology available today it would be no problem whatsoever."

The RTS has recently formed a technical sub-committee consisting of retired civil and mining engineers. They are examining what surveys are needed for these historic tunnels to re-open and ensuring that they are safe for public use. They are also researching the activities of the Canals and River Trust and Sustrans (a charity promoting travel by foot, bike or public transport), both of which have re-opened and managed long historic tunnels for leisure use.

Above: The entrance pipe near the Blaencwm portal

Below: The reinforcing steel ribbed section

The technical sub-committee is also working up designs for the re-opened portals with their approaching cycle paths to calculate the volume of material to be removed and to create designs ready for consultation with the local communities and planning authorities.

"Armed with information about other historic tunnels the RTS aims to get an agreement with the Heritage Lottery Fund, HRE and the Welsh government

about the type of survey that is appropriate," says Mackey. "Indications are that a detailed visual inspection in conjunction with a tap survey is the usual practice and is in line with the accepted regime of Network Rail. Such a survey would avoid the substantial cost of having to excavate and re-fill any portal."

Once a detailed survey is completed the scope of works will become clear but these will include constructing a road surface, lighting (including emergency lighting) and CCTV. It is assumed at the moment that the existing ventilation shaft can be repaired and pressed into service again – perhaps with the addition of fans.

On the question of the tunnel lining, apart from the necessary remedial work, Mackey would like to see it kept in its original state, complete with "the soot of the trains on the ceilings and walls."

The tunnel is virtually straight and has only a gentle incline in the first two-thirds from the Blaencwm end.

When it was open, on a good day you could stand at one end and see a faint pinprick of light at the other. Its length, however (it would take around 20 minutes to cycle through it), means that restorers have to be mindful of personal security and emergency access. Current thinking is for a golf-style buggy to be deployed to pick up any casualties.

Rough estimates put the cost of reopening the Rhondda Tunnel and transforming it into a cycling and walking route at between GBP 7.5-9M (USD 9.2-11M).

The RTS's activities raise enough cash to keep its campaign going but are not intended to fund the building work. This money will have to come from the public purse and organisations such as the Heritage Lottery Fund.

"In the great scheme of things it's not a lot of money and we may even be able to apply for EU funding before we leave," says the ever-optimistic Mackey, adding that he would like to see the tunnel open by 2020.

He's also hoping that financial help will be forthcoming from the neighbours. Vattenfall is building a 92-turbine wind farm on the land above the tunnel and a cheap supply of electricity would be very welcome.

In any funding application it will be vital to show how running and maintenance costs will be met in the future and a recent survey conducted by RTS at the Two Tunnels Greenway project in Bath revealed that tunnel users would be willing to pay a nominal toll.

Local residents would be expected to have free access

Adding value to society

For Han Admiraal, chair of the International Tunnelling Association's Committee for the Use of Underground Space (ITACUS), projects that breath new life into disused tunnels are a way of adding value to society.

"They reveal a piece of your heritage which has more or less disappeared, particularly in the UK where the Beeching cuts led to a lot of tunnels being walled up. It's sad because a huge amount of elbow grease went into building these conduits – especially the first of them."

He believes in the case of the Rhondda Tunnel it's important to push this heritage message, suggesting the cycle path becomes as much an exhibition and educational space as it does a visitor attraction and route from A to B.

"So much has happened in that region and there is so much heritage there, why not make the tunnel into something more than a big, dark hole in the ground that you just cycle through," he says. "I would recommend they show something that demonstrates why the tunnel was built in the first place. I can imagine that by using modern video projection techniques you could turn the Rhondda Tunnel into a dynamic and virtual museum."

He cites the New York Lowline initiative and the Lyon Croix-Rousse walking and cycling tunnel as perfect examples of how underground spaces can be turned into visitor attractions.

Lowline, formerly known as the Delancey Underground, is an old tramway depot in Manhattan's Lower East Side that campaigners want to turn into an underground park. The depot opened for trolley passengers in 1908 but has been unused since 1948 when the trolley service was discontinued. If the plan goes ahead, solar technology will be used to turn the depot into much needed green space.

The latter tunnel – Le Tube – is a 1,763m tunnel under Croix-Rousse hill (www.youtube.com/watch?v=u3D9-9Oz130&feature=youtu.be). Originally constructed as an emergency tunnel for a parallel road tunnel it was then decided to add "entertainment" in the form of music and permanent light shows projected on to the tunnel walls.

Admiraal also said redevelopers must be mindful of the social and physical safety of future tunnel users and that eliminating water ingress and installing sufficient lighting would be top of the agenda.

"You wouldn't want to light it up completely but people need to be able to see that nobody is hiding and about to spring out at them," says Admiraal.

He also advocated preventing cars from being able to pass through, as this would raise many additional safety considerations.

A means of rescuing cyclists or pedestrians would also be necessary, as would CCTV – and this raises the question of how these would be monitored.

"I worked on a project in the Netherlands where we installed CCTV cameras that were permanently in operation but not monitored all the time. As long as there was movement in the tunnel nothing happened, but if someone stood still for a long time or if someone had fallen and couldn't reach an emergency button, an alarm would trigger and alert the operations room where they could use the cameras to locate the problem.

"That introduces a high level of sophistication into a tunnel because it means you would have to monitor it during operational hours. You could have the tunnel permanently in use or you could close it off at night. It all depends on what the status of the tunnel is and whether it is private or part of the public road network. If it is open 24/7 then monitoring may have to be outsourced to a security company."

The private/public dynamic could also be the crucial deciding factor in whether tunnel restoration projects such as Rhondda go ahead.

"I would suggest that any local government would be very happy if citizens took ownership and responsibility," says Admiraal. "You can sit back and leave it to government – but I'm not sure that will get you very far."

The Lowline project aims to transform a New York tram depot into an underground park Photo credit: RAAD Studios

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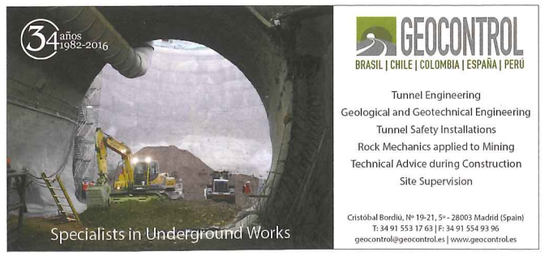

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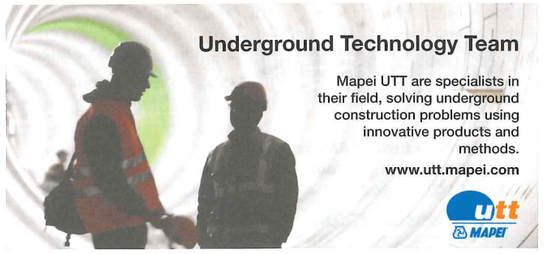

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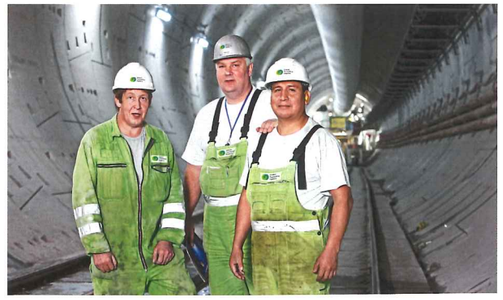

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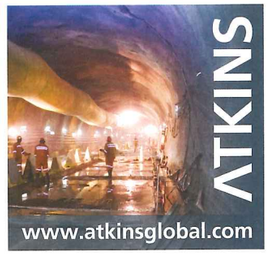

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What's on

2017

The George A. Fox Conference
24 January 2017
New York City, USA
The 2017 George Fox Conference theme is New Tunneling Technologies. Industry experts will present innovative and new ideas used in the design and construction of underground structures and tunnels. Topics will include fire protection, fire proofing, international pre-cast segmental lining innovations and new FHWA tunnel inspection requirements. Additionally, the risks and history of Design-Build and Public-Private-Partnerships (PPP or 3P) contract models will be discussed. A tunneling industry update and some applicability and lessons-learned presentations will round out this exciting conference.
www.georgefoxconference.com

4th Arabian Tunnelling Conference
21-22 February 2017
Dubai, UAE
The ATC is the number one networking hub of Tunnelling and Underground Space experts and in the region.
www.soeuae.ae

First (Costa Rican) National Congress of Underground Works
21-22 February 2017
Dubai, UAE
This ITA-endorsed conference is to be the first hosted in Costa Rica. It is organised by ACROS, the Costa Rican underground works society. Further details are yet to be confirmed, please see the society's Facebook page for more information.
www.facebook.com/ctos.acg

4th Brazilian Tunnelling Congress and Latin American Tunnelling Seminar
3-6 April 2017
Sao Paulo, Brazil
The fourth edition of the Brazilian Congress of Tunnels and International Seminar: "Latin American Tunneling-LAT 2017", will take place in parallel to the 9th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground.
www.tuneis.com.br

SEACETU 2017
18-19 April 2017
Subang Jaya, Malaysia
The Institution of Engineers, Malaysia is hosting the Southeast Asian Regional Conference and Exhibition on Tunnelling and Underground Space in March/April 2017 in Subang Jaya, which is approximately 27 km from Kuala Lumpur City Centre (SEACETUS2017). The conference will offer case studies and strategies that demonstrate innovation, skills and best practices, and help delegates understand the technologies and techniques guiding the tunnelling industry.
www.myiem.org.my

Symposium on Tunnels and Underground Structures in South-East Europe
4-5 May 2017
Zagreb, Croatia
ITA Croatia is organising the 7th International Symposium on Tunnels and Underground Structures in South-East Europe with the title SEE tunnel. With the support of ITA and our neighbouring countries the organisers are glad to open the possibility to speak about ideas, technical possibilities and financial interests.
www.promovere.hr/congress

Swiss Tunnel Congress
30 May - 1 June 2017
Lucerne, Switzerland
The Swiss Tunnelling Society organises the annual Swiss Tunnel Congress at the KKL Lucerne. During the last few years, this annual STS event has developed into the main congress for tunnelling experts in Switzerland, originally evolving from the AlpTransit congresses. There are usually around 800 experts from 15 nations attended the high quality presentations and additionally enjoyed the traditional excursions to large construction sites within Switzerland and the surrounding area which took place.
www.promovere.hr/congress

Rapid Excavation and Tunnelling Conference 2017
4-7 June 2017
San Diego, California
RETC is the only conference with a dedicated focus on the developments, technology, trends, and innovations that directly affect the tunnelling and underground construction industry. It is a premier event.
www.retc.org

World Tunnel Congress 2017
9-16 June 2017
Bergen, Norway
The theme of the 2017 World Tunnel Congress is 'surface problems - underground solutions'. The Norwegian tunnelling industry produces tens of kilometres of drill and blast tunnel every year through the complex topography of this Nordic country.
www.wtc2017.no

Geo M East 2017
15-19 July 2017
Sharm El-Sheik, Egypt
Recent rapid construction in Egypt has provided great opportunities for tunnel engineers to use their knowledge and talents to solve many challenging problems with innovative solutions and cutting-edge technologies.
www.geomeast2017.org

ICTUS 2017
28 August - 1 September 2017
Seoul, South Korea
The Korean Tunnelling and Underground Space Association welcomes you to Seoul. The theme is "Frontier Technologies in Tunnelling and Underground Space Technologies". It will play host to these sessions: innovations in mechanised tunnelling, developments in UG space tech, improvements in conventional tunnelling, structural and hydraulic interactions, extreme conditions, and stability.
www.i-asem.org

Underground Infrastructure of Urban Areas
24-26 October 2017
Wroclaw, Poland
This ITA endorsed conference is being organised by Wroclaw University and the Polish Tunnelling Group.
www.pbp-ita.pl/.org

Aftes International Congress
13-15 November 2017
Paris, France
The congress of the French tunnelling association returns to Paris in 2017.
www.aftes.asso.fr

Stuva Expo 2017
6-7 December 2017
Stuttgart, Germany
The 2015 trade fair accompanying the Stuva conference exceeded all expectations. With 1,850 conference delegates and more than 550 trade visitors, around 2,400 visited in 2015.
www.stuva-expo.com/en/

2018

NASTT No Dig 2018
25-29 March 2018
Palm Springs, USA
Since 2001, this show has nearly doubled in size, keeping pace with the rapid growth of our industry. Cutting-edge technologies are continually being developed and introduced.
www.nastt.org

World Tunnel Congress 2018
20-26 April 2018
Dubai, UAE
The World Tunnel Congress heads to the United Arab Emirastes in 2018, and demonstrates the rise of the Middle East to the centre stage of the global tunnelling market. Experience true Arabian hospitality and enjoy Dubai, the world's most cosmopolitan city.
www.uaesocietyofengineers.com

2019

World Tunnel Congress 2019
3-9 May 2018
Naples, Italy
The World Tunnel Congress heads to the Naples in 2019 following a dramatic win at the vote in San Francisco in 2016.
www.facebook.com/events/1753343481565751/

ECSMGE 2019
3-9 May 2018
Reykjavik, Iceland
The Icelandic Geotechnical Society are pleased to welcome you to the XVII European Conference on Soil Mechanics and Geotechnical Engineering, held in the Icelandic capital. The theme of the conference is "Geotechnical Engineering, foundation of the future" and will embrace all aspects of geotechnics.
www.ecsmge-2019.com

The British Tunnelling Society

The BTS has a membership of over 814 individual and 266 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Regular BTS monthly meetings are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month. In recent years, the BTS Young Members (BTSYM) group has also begun hosting its own events.

The Harding Memorial Lecture: Tunnelling impact assessment for utility pipelines and tunnels
19 January 2017
An important consideration when planning and carrying out tunnelling works is the impact that those works may have on Third Party assets, particularly in cities. Damaging ground movements and loads may be caused by the tunnelling itself and/or by associated works for shafts. The impacts of tunnelling on buildings throughout the world have been widely reported but the impacts on utility apparatus have not received such detailed and extensive attention in the literature. The principal purpose of this lecture is to consider strategies and methods of impact assessment for utility pipelines and tunnels. The content is informed by numerous investigations into pipeline failures and consideration of the geo-environment of pipelines in cities which may render conventional analyses unreliable or even intractable. The lecture will discuss the current, mainly analytical, approaches to the problem and suggest other more broadly risk based methods which may be considered for future application. The emphasis will be on simplifying the assessment process to reflect the uncertain condition of the pipelines and other factors but retain asset protection essential to utility providers.
Speakers: Barry New, Geotechnical Consulting Group

Joint BTS/MinSouth Meeting - The Alaskan Way Viaduct Replacement project (SR99)
9 February 2017
The Alaskan Way Viaduct, an elevated section of State Route 99 in Seattle, was built in the 1950s, and decades of daily wear and tear have taken their toll on the structure. Because of the viaduct's age and vulnerability to earthquakes, replacing it is critical to public safety. The project ran into difficulties in December 2013 resulting in years of delays and some impressive work to access and repair the 17.5m-diameter machine. Following a couple more hiccups after the machine restarted, the client reported that tunnel excavation had passed the halfway point on 3 October 2016 and the machine was making good progress. This project has had a great impact on the US tunnelling industry; surely a talk not to be missed.
Speakers: TBC
Please note that this event takes place on the second Thursday of February

Finsbury Park squareworks
16 March 2017
The Finsbury Park scheme being presented includes square works in the tunnel and works to shaft one, undertrack crossings and works to another shaft three to provide improvements to this existing London Underground Station.
Speakers: TBC

The Harding Prize
20 April 2017
The annual competition is named in honour of Sir Harold Harding, founder chairman of the BTS and is open to engineers aged 33 or under. Entrants must submit an original paper relating to any aspect of tunnelling.
Speakers: TBC

If you have a topic or project you feel would be suitable for a BTS evening presentation, please contact:

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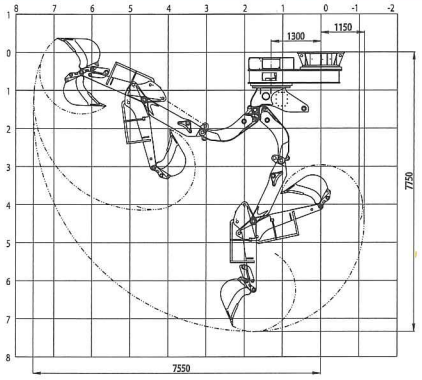

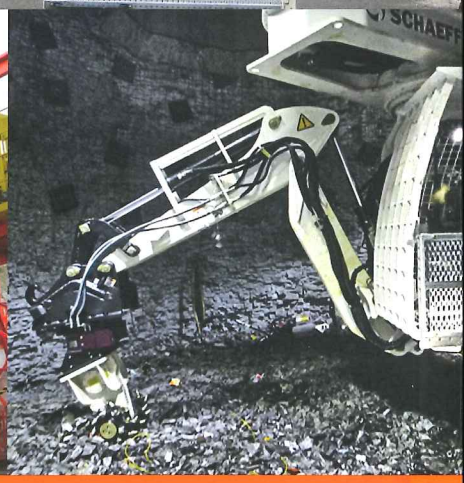

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