

INTERNATIONAL EDITION

September 2014

Tunnels

AND TUNNELLING

Work races ahead on Rio de Janeiro's Metro Line Four. Officials hope to open the route in time for the Olympic Games

RIO REALISED

Latin America • Harding Prize • BTS Conference



THE PATH OF LEAST RESISTANCE

Carving paths through the earth's most difficult obstacles is already a monumental task. Having an experienced partner that streamlines the entire tunneling operation puts you a step ahead.



AT ROBBINS WE KNOW TUNNELING IS TOUGH, BUT WE BELIEVE YOUR PARTNERSHIPS SHOULDN'T BE.

Not only does Robbins provide the best designed machine for your project, we offer unrivaled support from project onset to machine buy-back and everything in between. While the underground has no guarantees, partnering with Robbins does.



THEROBBINSCOMPANY.COM

OH CANADA

WITH THE autumn conference season upon us the tunnelling community is next month heading to Vancouver to take part in the Tunnelling Association of Canada's biennial conference.

Canada is a land of opportunity for tunnellers, with the cities winning investment in transport infrastructure and the country's massive wilderness playing host to hydropower and mine developments works. With British Columbia hosting the 2014 gathering, delegates will be in reach of Vancouver's recently completed 7km twin bore metro line and the Port Mann water tunnel.

Underway in the city is the Evergreen Line, an 11km extension to the Greater Vancouver rapid transit, which includes a 2km tunnel. And two water tunnel projects are proposed: The Second Narrows Water Supply Tunnel Project is an 1.1km-long tunnel with preliminary design of the project is currently underway and construction planned to commence in 2017; The Annacis Main No 5 Water Tunnel is a water supply tunnel beneath the Fraser River connecting the Greater Vancouver suburbs of New Westminster and Surrey. Conceptual design is currently underway for the project, with detailed design to follow and underground construction planned to commence sometime in 2018.

Outside of the city, BC is seeing an increase in activity in hydroelectric developments. AltaGas recently completed the Forrest Kerr Hydro Project, which includes an extensive amount of underground work, including over 5,000m of access, tailrace and power tunnels and an underground powerhouse cavern (144m long, 17m span, 26m height).

The company is also constructing the McIymont Creek Hydro Project, which includes an intake, surface powerhouse and a 2.7km-long Power Tunnel. Tunnel excavation commenced Easter 2013. The project is scheduled for completion in mid 2015.

The proposed John Hart Generating Station Replacement Project is owned by BC Hydro and is located in on Vancouver


Jon
Young
Editor



Island. The massive CAD 1bn (USD 0.91bn) project, for which the principal contract was awarded earlier this year, includes the construction of a 2.1km-long rock tunnel, an underground powerhouse, and associated shafts and access tunnels. Underground construction is scheduled to commence this autumn.

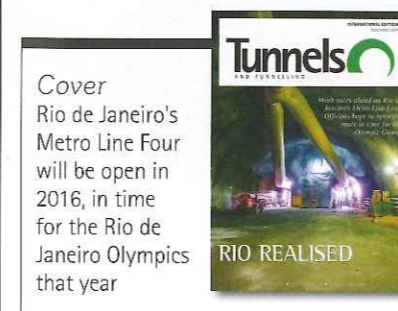
Innergex Renewable Energy is constructing three projects in British Columbia. The Upper Lillooet Hydroelectric Project, which includes two facilities, Upper Lillooet River Hydroelectric Facility and Boulder Creek Hydroelectric Facility requires 7km of tunnelling in total. The tunnels are mainly being cut by drill and blast.

A third and separate project being constructed is the Big Silver Hydroelectric Project. The tunnel is 5.5m high and 6m wide, with a total length of 1,800m. Tunnel excavation is scheduled to begin later this year.

Taking stock of the opportunities in BC is just scratching the surface of what Canada proper holds for tunnellers. For more detail on activities in BC and elsewhere in Canada see the October edition of Tunnels North America and visit the show in Vancouver 

editor@tunnelsonline.info

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



Next issue

The next issue of Tunnels and Tunnelling is going to be distributed at the Bauma China International Trade Fair for Construction Machinery. Ready for the event, we are preparing regional reports on the Liaoning Water Transfer Project, and the Bangkok Metro.

This month...

10 YEARS AGO

Construction of the USD 5.28bn Kaohsiung Metro in Taiwan hangs in the balance following a series of cave-ins and other incidents. Kaohsiung City Mayor Frank Hsieh said, "[We must] see if the geological problems can be overcome. If not, then we'll see if the project should be halted." *Tunnels and Tunnelling, September 2004, p.8*

30 YEARS AGO

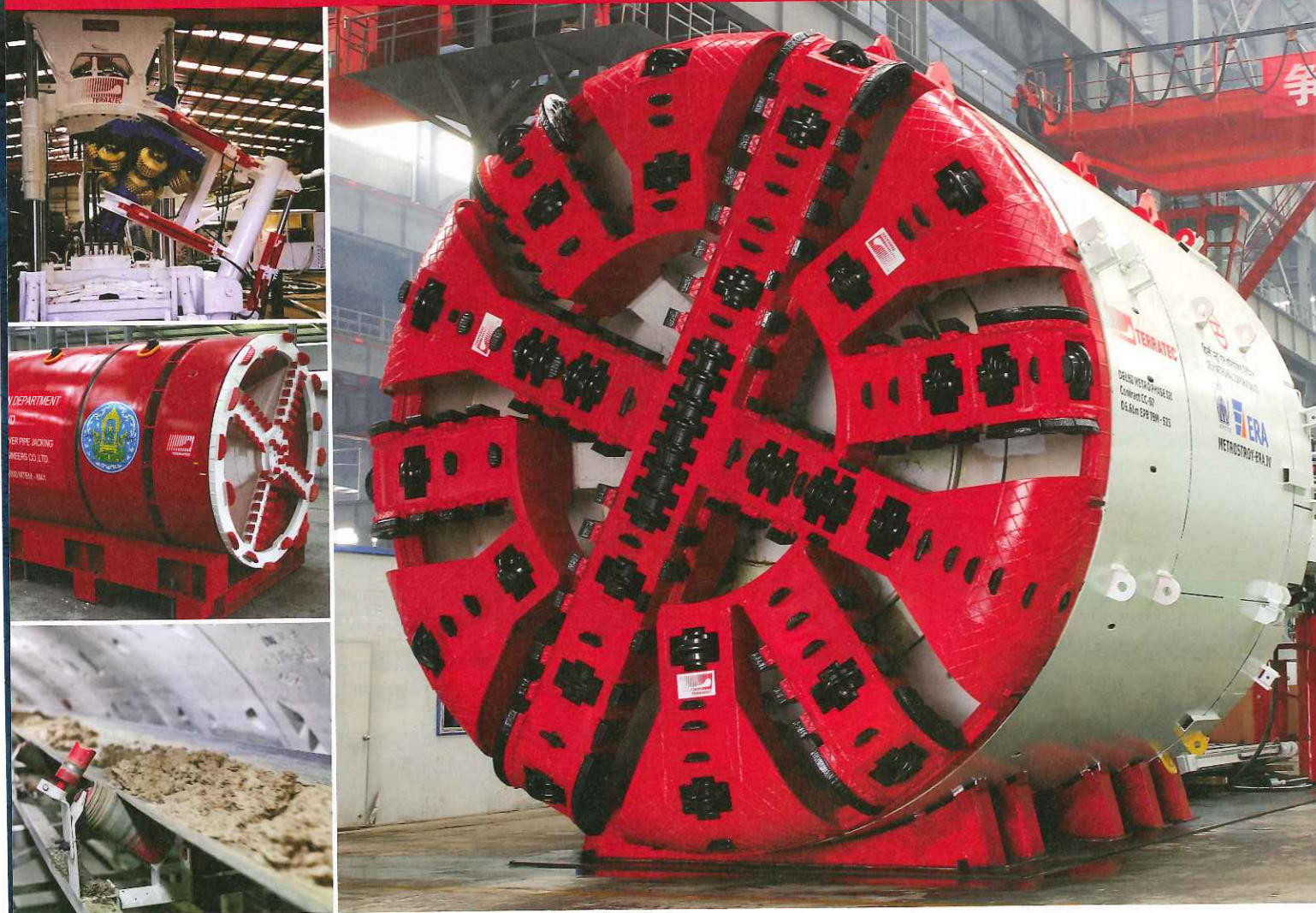
After finding themselves linked following the takeover of a third company, Hochtief and Leighton have come to a mutual agreement to avoid direct competition. Hochtief of West Germany cedes the Asia Pacific region to Leighton of Australia as its special sphere of operation. The partnership came about when Leighton took over Thiess, of which Hochtief was a principal shareholder. *Tunnels and Tunnelling, September 1984, p.8*

40 YEARS AGO

The Harding Prize has been launched. The British Tunnelling Society has introduced an annual competition, open to anyone under the age of 25, for written material that contributes to the advancement of tunnelling. Organised by the Association of London Graduates and Students on behalf of the BTS. Winning entries will be published in Tunnels and Tunnelling. *Tunnels and Tunnelling, September 1974, p.15*

ALWAYS ADVANCING

www.terratec.co



TOTAL TUNNELLING SOLUTION

Since 1990, TERRATEC designs and manufactures Tunnel Boring Machines, Raise Boring Machines, Conveyor Systems and other equipment for the tunnelling and mining industry.

Having its main quarters and engineering centre in Australia, TERRATEC has other six wholly own subsidiaries strategically located in different regions through the globe to attend the worldwide demand. At present, over thirty TERRATEC boring machines are working across five continents.



Left: Rio de Janeiro Metro Line 4, page 20

News

- 7 News
The latest project updates, corporate moves and tunnelling advances from around the world
- 14 Business news
Corporate and personnel changes, key decisions and financial news from global tunnelling companies
- 18 Big picture
This month's big picture shows the hard rock conditions encountered on a Delhi Metro drive

Latin America

- 20 Rio de Janeiro Metro
Rhian Owen
Rio de Janeiro's Metro Line 4 stays on track for an Olympic opening deadline

Insight

- 29 Fire protection
Patrick Reynolds
Interest is rising in active intervention through the use of fixed fire fighting systems, particularly water mist setups

BTS

- 35 BTS Conference 2014
The UK's foremost tunnelling event returns to the nation's capital at the month's end
- 39 Crossrail C310: Thames Tunnel
Riku Taurianen, Hochtief-Murphy
Andreas Raedle, same
May's British Tunnelling Society meeting featured a presentation on works undertaken for the Thames Tunnel portion of Crossrail

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

editor@
tunnelsonline.
info



A world of information fully archived and searchable at the click of a mouse

www.
tunnelsonline.
info



- 49 Harding Prize Winner
Edward Batty, BFK JV
This year's prize winning paper was presented for consideration by a young engineer on working on the Crossrail project's Bond Street Station, part of the Western Tunnels portion of works

Contributors

EDWARD BATTY
Edward is the winner of this year's Harding Prize. The prestigious award is presented by the BTS to any engineer under the age of 33 who submits the best paper. A graduate from the University of Surrey, he has spent the first two years of his career working for the BAM Ferrovial Kier joint venture on Crossrail Contract C300 and 410, the Western Tunnels and Caverns Project. Read his award-winning paper on page 49.

**ANDREAS RAEDLE
RIKU TAURIANEN**
Andreas is the Hochtief-Murphy joint venture's technical and risk manager while Riku is project director for the same. They work on Contract C310 for the Crossrail project, which covers work required for the Thames Tunnel portion of the rail link. They gave a presentation of the work undertaken by the teams at the May evening meeting of the British Tunnelling Society. Read the meeting write-up and questions from the floor on page 39.



KVMRT PROJECT

Sungai Buloh to Kajang Line
Kuala Lumpur, Malaysia

Successful breakthrough of both CREG EPB machines on the first MRT line

CR50 completed first drive on 24 December 2013 – rates up to 345 m/month

CR51 completed first drive on 16 January 2014 – rates up to 330 m/month

CTE Ltd congratulates Main Contractor MMC Gamuda

and subcontractor Nanyang on a job well done

and looks forward to the second drive for both machines later this year

NOW AVAILABLE

Hard rock TBM's – Kelly type and Double Shields
Using WIRTH technology and experience.

CTE Limited

Unit 908, Block B, Phileo Damansara II, No. 15 Jalan 16/11, off Jalan Damansara,
Section 16, 46350 Petaling Jaya, Selangor, Malaysia

Tel: +603 7954 0314 Fax: +603 7931 1977 Email: enquiries@cte-limited.com

LTA ANNOUNCES EASTERN REGION LINE AND DTL3 EXTENSION ALIGNMENTS

Singapore The Singaporean Land Transport Authority (LTA) has announced the rail alignment and station locations for its Eastern Region Line, which will run with the Thomson Line as a single route. When completed it will become Singapore's sixth rail line, and be called the Thomson-East Coast Line (TEL).

An LTA spokesman said, "The 13-kilometre East Coast stretch of the TEL will connect commuters living in the eastern parts of Singapore and who are

not directly served by the rail network currently, such as those in Tanjong Rhu, Siglap, Marine Parade, Upper East Coast and Bedok South, to the heart of the city.

"As part of the 43km-long TEL, the East Coast stretch will also connect commuters to the north-south corridor. Fully underground, this new stretch will have nine stations, including one interchange station with the Downtown Line (DTL). In all, TEL will have 31 stations, of which seven are interchanges."

Concurrently the LTA finalised the alignment for the Downtown Line Three Extension (DTL3e). This new extension will be 2.2km long and consists of two stations, including the interchange station with the East Coast stretch of TEL.

The East Coast stretch of TEL will be completed in two stages. The first seven stations from Tanjong Rhu to Bayshore will be ready in 2023, while the remaining two stations, the DTL3e and the depot will be completed in 2024.

Zublin/Hochtief to build Rastatt rail tunnel

Germany-Switzerland A joint venture led by Züblin and Hochtief was commissioned by DB Netz AG to deliver the shell construction of the "Rastatt Tunnel". The tunnel project is part of planning approval section 1.2 of the new railway route between Karlsruhe and Basel. The contract volume amounts to approximately EUR 312M (USD 417.6M).

The core element of the project is the twin-tube rail tunnel which passes directly under the city area of Rastatt and will be bored mechanically with a hydro shield TBM over a length of around 3.8km. The contract also includes the trough sections to the south and north as well as a supply shaft and an operational building.

"As a traditional company from the state of Baden-Württemberg, we are proud to play a major role as technical leader in another trail-blazing inner-city rail construction project," underlines Edgar Schömig, Director of Ed. Züblin AG, in view of the new large contract.

"We are very pleased that, with this project, we will be building an important part of Deutsche Bahn AG's main north-south railway

route. Our experts with their expertise in tunnel boring machines are thus once again involved in the upgrading of modern, sustainable transportation infrastructure in Germany," says Wilfried Rammler, General Manager of HOCHTIEF Infrastructure GmbH.

Work will start on the project in November 2014 and conclude in mid-2018.

Proposed MTA budget funds Second Avenue Phase Two

USA MTA president and CEO Thomas Prendergast proposed allocating USD 1.5bn for environmental study, design and tunnelling of Phase 2 of New York's Second Avenue Subway project.

He addressed the New York State Assembly Standing Committee on Corporations, Authorities and Commissions on 7 August regarding the Metropolitan Transportation Authority's (MTA) 2015-2019 Capital Program. The program will be submitted to the MTA board later this year and then forwarded to the Capital Program Review board in Albany.

Phase One of the Second Avenue Subway, between 96th and 63rd Streets, is expected to complete in 2016. Phase Two concerns the segment between 125th Street and 96th street, with

an existing tunnel between 99th and 105th Streets.

Two Delhi Metro projects hole through

India TBM manufacturer Terratec announced two TBM breakthroughs on metro contracts in New Delhi, India. The breakthroughs were on the CC-07 and CC-24 projects for Delhi Metro Phase-III.

On 31 July, Terratec's TBM working on CC-07 completed excavation on the down line from the Jama Masjid Station to the Lal Quila Station. The breakthrough ceremony was held in the presence of Contractor representatives from the joint venture between Metrostroy of Russia and ERA Infra Ltd. of India and client DMRC.

On 2 August, the TBM working on CC-24 accomplished another breakthrough from the Hazarat Nizamuddin Station to the Ashram Station. The TBM has advanced a total of 1. The CC-24 contractor is a joint venture between J. Kumar Infraprojects of India and China Railway Third Group (CRTG).

The next drive for TBM S25 is scheduled to complete the line between the Vinoba Puri Station and the Ashram Station.

Both machines are 6.61m in diameter with a

900kW VFD electric driven cutterhead. They are EPBMs and are designed for either excavating soft ground with cutting tools or mixed ground and rock using up to 33 no.17" roller disc cutters. Both TBMs have active articulation and two-component grout backfilling systems.

The geology encountered on CC-07 included large quantities of fresh, very hard (up to 200MPa) and very abrasive quartzite. In addition to sections with a full face of rock, there were sections with very variable mixed ground conditions with numerous large diameter boulders.

Further Seoul sinkholes found by inspectors

South Korea The Seoul city government on 18 August 2014 announced that it had found five more empty pockets under the Seokchon Underpass in Songpa District, following its discovery earlier this month of a sinkhole in the ground and two empty pockets underneath that area.

It is possible that the formations were the result of ongoing underground tunnel construction to make way for an extended section of subway line No. 9, the Seoul Metropolitan Government said, while stressing that investigators will soon publish a conclusive report.

Port of Miami tunnel opens

USA On 3 August, the Florida Department of Transportation (FDOT) and the Port of Miami achieved an important milestone when the USD 1bn Port of Miami Tunnel opened for traffic. The project consists of twin tunnels under Biscayne Bay linking Port facilities on Dodge Island with a widened MacArthur Causeway and I-395.

Florida Governor Rick Scott had previously dedicated the tunnel on May 19 but the opening was continuously delayed for various problems and repairs, including issues with the ventilation. "We had a problem with one of the fans, then we had a problem with two fans. Soon as we had problems with two fans, we took all the of fans down. we brought them to the manufacturer," Christopher Hodgkins, Vice President of Miami Tunnel, told local media.

CBE to supply moulds for Sanyanlu road-rail tunnel

China CBE will supply 30 segment moulds for a new double function twin tube tunnel at Wuhan, China. The new Sanyanlu tunnel in Wuhan will be part of the first section of the Metro Line Seven, which includes 19 stations over a total length of 30.9km.

The combined road-rail tunnel will have an external diameter of 15.2m. This contract signed with the Chinese company Shizheng confirms once again the leading position of CBE Group for large diameter segment moulds.

A CBE spokesman said, "The supply by the Chinese subsidiary of CBE Group comprises three sets of segment moulds with an internal diameter of 13,900mm, an external of 15,200mm, a thickness of 650mm and a width of 2000mm.

"Each ring will be

composed of ten concrete segments: seven standard, two counter-key and one key segment. Concept and layout of the moulds are entirely in the hands of the design office based in France, the manufacturing will be carried out in the CBE factory at Yangling in China in order to reduce the transport costs to Wuhan, a city with more than 10 million inhabitants in the centre of China in the province of Hubei."

The tunnel lies between two bridges and comprises two tubes with a length of 2,590m each and will be excavated 40m under the Yangtze River. The CBE spokesman adds that it will also be the first tunnel in China with a double function: the upper floor will accommodate road traffic on three lanes, the lower part will be dedicated to the metro line as well as the technical and safety systems.

The spokesman added, "The experience of CBE Group in designing and manufacturing tunnel

segment moulds with large diameters is based on more than 390 projects carried out since 1987. These realisations include the world's largest tunnels, the Alaskan Way Viaduct Replacement Tunnel in Seattle (17m), the road tunnel Waterview (14m) in New Zealand, the Strait Road Crossing Tunnel (13.2m) under the Bosphorus in Turkey, and also the tunnels of the motorway M 30 in Spain (14.7m) and the Groene Hart Tunnel (14.5m) in the Netherlands."

Second Tibetan railway opens to public

China A second railway line in southwest China's Tibet Autonomous Region, an extension of the Qinghai-Tibet railway, the world's highest, was officially put into use on 15 Aug. 2014, Xinhua News Agency reported.

The 251km railway line links the regional capital Lhasa and Xigaze, the second-largest city in the region. It reduces the travel time from the current four hours by highway to around two hours.

The new railway brings the total length of operating railways in Tibet to 802km. Construction of the railway started in 2010 with an investment of CNY 13.28bn (USD 2.16bn).

Due to complicated geological conditions, numerous bridges and tunnels and hefty investment in environmental protection, the cost of the railway exceeded (USD 8,000) per metre, making it China's most expensive. The Lhasa-Xigaze railway represents a new stage in Chinese rail construction, Xu Hongchun, the railway's chief designer added. "It demonstrates that China has mastered mature technologies for high plateau railway construction, he said.

Its 116 bridges and 29 tunnels account for 46 percent of the total length of the route.

PERTH AIRPORT LINK TUNNEL ANNOUNCED

Australia Western Australia Premier Colin Barnett has released details of a new 8km long twin tube tunnel, which will be a major part of the AUD 2bn (USD 1.86bn) Forrestfield-Airport rail link in Perth. Construction is due to start in 2016 with completion expected in 2020.

"The rail line will head east from the Midland Line near Bayswater Station and then tunnel under the Swan River and Tonkin Highway before reaching the airport and then go on to Forrestfield," Mr Barnett said.

"This Forrestfield-Airport Link project represents a real game changer in terms of public transport in this city.

"For the first time people will be able to catch a train to the airport and importantly, this will also open up a brand new rail corridor to the eastern suburbs and foothills, allowing a 20-minute rail journey into the Perth central business district.

"It is a key infrastructure project that furthers the long-term strategic interests of the city by opening up Perth's eastern suburbs which

in the short term will also create hundreds of construction and engineering jobs.

"This rail line will bring enormous benefits to airport passengers and staff working at the airport. In particular, this will be a boon for Western Australia's thousands of fly-in fly-out workers who will no longer have to drive to the airport and leave cars parked there for weeks on end.

"The tunnels are a really exciting engineering project that also means this railway line can be built in the most timely fashion with the least disruption to residents, businesses, traffic and the airport."

The Premier said the plans showed there would be a station at Belmont near the present domestic terminal, a station under the Consolidated Airport at the current international terminal, and a bus-train interchange station in Forrestfield. The tunnels, which would become the longest section of underground rail in Perth, are expected to add an extra 20,000 boardings on the Transperth network by 2021.



To complete your whole.

SUBWAY (C LINE), ROME, ITALIA
Contractor Generale: METRO C SpA, Roma, Italia - Client: Roma Metropolitana s.r.l.

Products used: MAPEQUICK CBS SYSTEM, MAPEBLOX T, POLYFOAMER FP, SILICAJET ST, MAPEFILL, MAPEGROUT COMPACT, MAPEGROUT TISSOTROPICO, LAMPOSILEX

Underground Construction

From Mapei UTT line: Reliable technology for underground construction

Alkali-free set accelerators for shotcrete.

Products for mechanized tunneling: foaming agents for soil conditioning, polymers, sealants, lubricants.

Products for grouting and consolidation.

Products for concrete repairing, protection and coating.

Products for waterproofing: synthetic waterproofing membranes, waterproofing accessories.



Discover the world of Mapei:
www.utt-mapei.com, hq.utt@utt.mapei.com



TUNNEL DRIVE UNDER THAMES COMPLETE

Great Britain TBM Evelyn has completed a 3.4km drive under the River Thames from Wandsworth in south London to Earls Court.

The London Power Tunnels job saw National Grid and contractors Costain Skanska JV having to thread the TBM below the riverbed of the Thames and above the path of the proposed Thames Tideway Tunnel.

Finding the correct distance below the Thames was particularly tricky due to the presence of 'scour hollows' on the bed of the river and the risk of fissures in the London clay through which Evelyn was tunnelling reaching upwards to them, Costain stated.

The team had also to tunnel underneath the Imperial Wharf rail station without causing any

settlement that could damage the track above.

To avoid this, Costain said it was necessary to work continuously for two weeks, fixing the concrete ring sections in place immediately as tunnelling continued. Leaving any section of tunnel unsupported for any length of time between shifts could have led to voids developing and potentially causing settlement above.

The drive under the Thames also required converting Evelyn from open mode – where the TBM is open to the ground through which it is boring – to closed EPB mode to minimise settlement as work proceeds.

The drive took some six months to complete, following its launch in February this year.

Mexico's ICA wins major tunnelling contract

Mexico Mexico's largest construction company, ICA, has won a MXN 2.57bn (USD 197M) contract to build a tunnel aimed at reducing flood risks in the centre of the country. The Churubusco-Xochiaca tunnel project, which was awarded through public tender, includes the construction of a 13km tunnel that is scheduled to take 29 months.

London Underground begins search for additional trains

Great Britain London Underground (LU) announced last month that it has begun a search to secure additional Jubilee and Northern Line trains. It said combining the orders would ensure value for money for customers, and that the additional trains and modern signalling system will boost capacity.

An LU spokesman said, "The new trains will enable greater frequencies on the Jubilee and Northern lines and support Tube services for the proposed Northern line extension from Kennington to Battersea. LU has placed a notice with the Official

Journal of the European Union (OJEU) seeking expressions of interest to supply new trains for the Jubilee and Northern lines. A formal Invitation to Tender is expected to be issued in early 2015."

Spanish tunnel thieves thwarted

Spain A gang posing as builders were stopped at the last minute from carrying out their latest heist. Having located an empty property close to a bank in the city of Elche, Spain, they spent a month on tunnel operations in preparation for a robbery.

The tunnel was approximately 0.5m wide, and progressed carefully, avoided existing infrastructure including electricity lines, gas pipes, and sewers. According to Spanish daily newspaper 'El Mundo', three or four workers would arrive at 10am every day with tools, and leave at lunchtime "like most builders do".

The crew reached the bank after it closed, but a security guard spotted a torch in a security camera and raised the alarm. It is believed the robbers escaped back down the tunnel as police arrived.

The Elche Police Force believes the robbers intended to blow up the vault while the streets were deserted.

Istanbul Metro accepts Terratec TBM

Turkey An Istanbul Metro TBM successfully underwent workshop testing and was accepted by contractor representatives. Manufacturer Terratec held the acceptance ceremony on 28 August. The contractor is a joint venture of Gülermak, Kolin and Kalyon (the GKK JV).

The TBM is a 6.56m diameter EPB machine. The cutterhead has been designed to excavate Istanbul's mixed geology, which includes rock formations.

The tunnel's segmental lining will form universal reinforced concrete ring, with an outer diameter of 6,300mm, inner diameter of 5,700mm.

The TBM will be transported to Turkey and commence boring at site before end of the year.

The JV has been tasked with building a rapid transit line on top of the existing Istanbul Metro system between Mecidiyekoy and Mahmutbey. The new line will be 17.5km in length and

consist of 15 stations, the journey time between both locations will take only 26 minutes. It is expected to be in service by 2017.

Martin Herrenknecht calls for expansion of technology education

Germany Martin Herrenknecht sees a huge need for action to increase education and the promotion of young talent in the areas of science and technology, Herrenknecht announced last week.

In the future, German industry needs 90,000 newly trained engineers per year. Herrenknecht believes the nation needs to much more intensively provide for new technological advances and the young talent needed for this in all major engineer-driven areas.

Herrenknecht has been increasing his own commitment through targeted funding and supporting of technical and scientific educational institutions as well as related promotion of young talent.

"I too have only been able to create a globally leading company in specialised mechanical engineering because our en-gineers, technicians and skilled workers were able to build on excellent, progressive and practically applicable technical training," says Herrenknecht.

Jeju island link will not be built soon

South Korea The government is mulling over a USD 15.7bn project to build an underwater tunnel linking South Jeolla Province to Jeju Island, the Transport Ministry confirmed on 20 August, but added it is unlikely the project will be realized in the near future. The Ministry of Land, Infrastructure and Transport is reviewing the plan for a rail link that would connect the mainland and Jeju Island through an undersea tunnel for HSR.

Lee Tunnel partnership brings success

The slipformed, 40m wide and 70m high, dividing wall of the pumping shaft used:



7,210m³ of concrete



1,072t of reinforcement



24/7 working

and was completed by the MVB team in just 27 days.



Morgan Sindall, VINCI Construction Grands Projets and Bachy Soletanche are working together as MVB, combining world-class expertise, together with CH2M Hill, to deliver the Lee Tunnel for Thames Water. An essential step in providing the capital with a 21st century sewerage system. www.mvbjv.co.uk

Watch timelapse footage of the concrete pour here:



Crossrail's Jessica breaks through

Great Britain Crossrail's TBM Jessica has completed a new train tunnel from Limmo Peninsula, near Canning Town, breaking into Victoria Dock Portal in east London. The 7.1m diameter TBM completed the journey in nine weeks, travelling up to 41m per day.

The machine will now be dismantled, with parts returned to manufacturer Herrenknecht for use on other tunnelling projects.

Tunnel segments were made in Chatham, Kent and transported to Limmo by river barge. It is Jessica's second Crossrail tunnel drive, having already created one of the two tunnels forming the spur from Pudding

Mill Lane near Stratford to

Stepney Green.

Jessica's sister tunnelling machine, Ellie, will start the remaining twin tunnel from Limmo to Victoria Dock in the coming weeks.

Crossrail's rail tunnels are 83 percent complete, with TBM tunnelling due to complete early next year.

Andrew Wolstenholme, Crossrail chief executive said: "We continue to make good progress on Crossrail's tunnels. The end is now in sight on Crossrail's tunnelling marathon, but there is much more to do in the form of installing railway systems and fitting out the stations."

Guizhou tunnel collapse traps 13

China At least 13 people have been trapped after an under-construction tunnel collapsed

on 10 August in southwest China's Guizhou province, local authorities in Guiyang said.

The tunnel is being built on a highway in Shiqian County. The 13 people are estimated to be 600m away from the portal.

Excavators have been employed to rescue the trapped. Safety regulation officers, police and medics have also arrived.

Kuwait City metro network plans finalised

Kuwait The Ministry of Communications has reportedly finalised the layout for its new USD 20bn metro network in Kuwait City.

The three-line system would include 61 stations and cover the entire capital, according to Safat-based

Arabic daily newspaper Al Shahed.

A 23.7km line would run from Salwa to Kuwait University, with 19 stations.

A 21km line would run from Hawally, stopping at 27 stations to end in Kuwait City.

A third line would stretch 24km from Kuwait International Airport to Abdullah Al Mubarak area, passing through 15 stations.

The project will be implemented as a public-private partnership and construction is expected to begin in 2017.

Dartford Tunnel closed after asylum seekers found hidden in lorry

Great Britain The Dartford Tunnel, which is used by more than 130,000 vehicles daily, was closed when 13 suspected asylum seekers were found hidden in a lorry at the Dartford Crossing in late August.

Police were alerted after noises were heard from the back of a HGV approaching the tunnel under the River Thames. The men and women were taken to the port of Dover to be quizzed by immigration officials.

Lotte World Mall to involve tunnels

South Korea Lotte Group on 25 August cleared a hurdle in opening part of its Mall in Jamsil, by yielding to the government's demand to build underground tunnels for around the landmark.

OTTAWA LRT TUNNEL REACHES 50 PER CENT MILESTONE

Canada Rideau Transit Group (RTG) has excavated 50 per cent of the underground alignment for the Ottawa light rail project, it was announced August 11, with Premier Kathleen Wynne, Royal Galipeau, MP (Ottawa-Orléans) and Ottawa mayor Jim Watson touring the Confederation Line tunnel.

Mining started in October 2013, and RTG has excavated an equivalent of over 50 per cent of the tunnel volume, some 58,000m³ of the estimated 110,000m³ total. The majority of the remainder of the tunnelling operation will focus on the excavation of three station caverns.

Two roadheaders are mining out Lyon and Parliament stations, and the third should reach Rideau station to begin that mining operation by the end of the year. This project is on track and on budget and tunnel excavation is expected to be completed in the summer of 2016, the city announced.

"This public transit link will transform how we will move around Ottawa," said Premier Wynne. "I am committed to promoting public transit and creating jobs across Ontario. This incredible project is proof of what we as a province can achieve."

"The Confederation Line is an important job-creating project that will make public transit

faster, safer and more convenient for commuters in Ottawa," said MP Galipeau. "It will bring tremendous benefits to our City and the local economy, including thousands of new jobs, and we are pleased to see such great progress on the tunnel portion of the project."

"Work on the Confederation Line tunnel began only ten months ago," said Mayor Watson. "Since then we have dug more than 807 metres of tunnel and made progress on the caverns of the first two underground stations. There is a lot more to be done, but these are excellent results and I am grateful to all the work crews and the project management team for their exceptional performance."

The Confederation Line is a CAD 2.1bn (USD 1.9bn) project that is jointly funded by the Government of Canada, the Province of Ontario and the City of Ottawa.

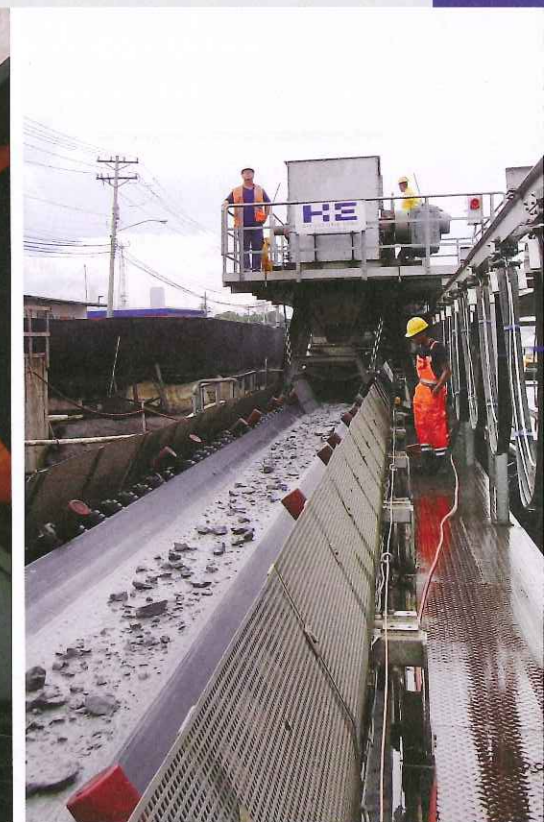
RTG has undertaken this first stage in Ottawa's future rail network. The 12.5km electric light rail system replaces existing diesel powered buses, providing rapid transit between Blair Station in the east and Tunney's Pasture in the west.

The route includes 13 stations and a 2.5km tunnel that will alleviate congestion through the downtown core.

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



www.tunnelsonline.info



Supporting the first Metro Line in Panama.

Panama, Panama City. Central America's first metro network will be built in Panama City. The largest infrastructure project since the construction of the Panama Canal is scheduled to be completed in 2014, when line 1 will be opened to traffic. It will have a length of 13.7 km and will serve twelve stations. Line 1 will run from the "Albrook Bus Terminal" in the south to the "Los Andes Shopping Mall" in the north, passing through downtown Panama City. During this tunneling project, the challenge for H+E was to guide the tunnel conveyor system safely through the narrow S-curve. Booster stations solved this problem to the utmost satisfaction of our customers and made the project a success.

Technical data:

- Tunnel diameter: 8.70 m
- Conveyor length: 4,225 m/ 3,398 m
- Belt width: 1,000 mm
- Capacity: 1,200 t/h
- Installed power: 5 x 160 kW
1 x 90 kW
4 x 160 kW
- Belt storage capacity: 2 x 600 m
- TBM: EPB
- Installation: 2012



H+E Logistik GmbH
 Josef-Baumann-Str. 18
 D-44805 Bochum
 Germany
 Phone +49 (0)234 | 950 23 60
 Fax +49 (0)234 | 950 23 89
www.helogistik.de

Malaysian MRT CEO resigns over accident

Malaysia Datuk Azhar Abdul Hamid has resigned over a construction site accident on the Kota Damansara Station site that claimed three lives. The Bangladeshi workers were killed when a concrete span at the site collapsed at 8.30pm.

Azhar said he had always been very strict over safety measures at MRT sites but such incidents had occurred over and over again.

"[Effective immediately] I am no longer the CEO," he told a press conference on 19 August. "I have done my best, but I have evidently failed and therefore will be handing over my duties."

"I was told that some security measures were not followed by the sub-contractors and if that really is the case, I will make sure MRT Corp never works with them again."

He added that despite his departure from the company, he would see the case through and ensure that the families of the deceased are given justice.

MRT's stakeholder relations and land management director Haris Fadzilah Hassan would take over until the Government appoints a new CEO.

Kota Damansara MRT Station, the Mass Rapid Transit station in Kota Damansara, located at north west of Kuala Lumpur.

Jacobs Associates promotes Smith

USA Jacobs Associates announced that Rick Smith, was recently promoted to Senior Associate. Based in the company's Seattle office, Smith has 27 years of geotechnical engineering experience for heavy civil design and construction, including underground structures for water, wastewater and transit, highway and railway bridges, support of deep excavations,

landslide stabilisation, and earth and rock fill dams.

A spokesman added, "He has been a key team member on several large underground projects in Seattle, including the Brightwater Conveyance System, University Link Light Rail Extension, Northgate Link Light Rail Extension, North Creek Interceptor Sewer, and the Fremont Siphon. Smith is currently managing geotechnical and trenchless services for the Rainier Valley Wet Weather Storage Project in Seattle, and the foundation design for several bridges for the Burlington Northern Santa Fe and Union Pacific railroads."

Murphy CEO steps down

Great Britain Following a board restructure at J. Murphy & Sons earlier this year, John Stack has decided step down as CEO of the company at the end of September. Matthew Behan will take over as interim CEO from 1 October.

John started his career with Murphy as a Graduate Engineer in 1982 on the Barrow Pipeline contract, and has since progressed through the ranks both within Murphy and externally.

He re-joined the business in 2008 and has been at the Murphy helm for the last six years, successfully driving the business forward through a period of great change and through what has been a very challenging time within the industry.

A Murphy spokesman added, "On behalf of the Murphy family, the Board of J. Murphy & Sons and all our employees, I would like to thank John for his contribution to the business and wish him every success for the future."

Aitken becomes B&V European water MD

Europe Scott Aitken has been appointed Managing director of Black & Veatch's water business in Europe. The

new leader will assume full management responsibility for the company's asset lifecycle services including professional services, design-build and operate-maintain asset management ambitions in the region.

"Meeting our business goals requires an effective leader with a deep understanding of the UK and European water sector," said Cindy Wallis-Lage, President of Black & Veatch's global water business. "Scott has both these qualities in abundance. He is a proven leader with a huge depth of water industry experience in both construction and professional services and is ideally placed to provide the strategic direction needed to grow our UK opportunities and deliver a long term sustainable and resilient water business."

Aitken brings more than 27 years' European water market experience to this key position. He is also familiar with the energy sector having created and directed a renewables start-up. Under previous directorships he delivered year-on-year business growth, in both revenue and margin.

As managing director Aitken will be the face of the business and will work from the company's Redhill and Falkirk offices.

Oil price



Values are taken on 12th of each month.

Central bank rates

	Rate (%)
AUD	2.50
BRL	11.00
CAD	1.00
CHF	0.25
CNY	6.00
EUR	0.15
GBP	0.50
INR	8.00
JPY	0.10
NZD	3.50
USD	0.25

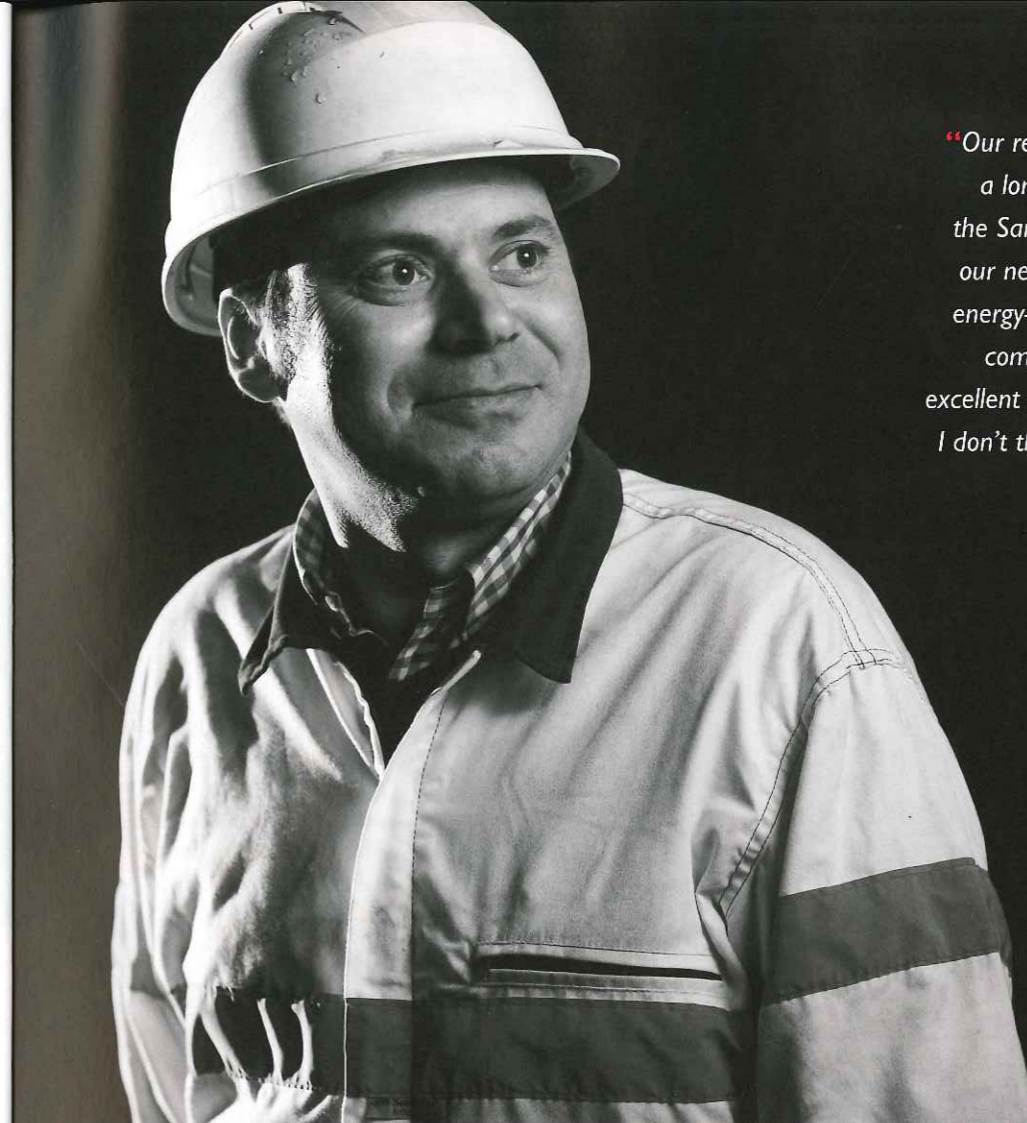
Rates are taken on the 12th of each month.

HCC net profit up 41%

India Contractor HCC has registered a net profit of INR 271M for the first quarter of FY 2014-15 compared to INR 19.2 crore in the corresponding period last year. This was the fifth consecutive quarter of improving results.

The turnover in Q1 stood at INR 1,043.5 crore compared to INR 1,149.6 crore in the previous year.

Commenting on the company's performance, Praveen Sood, Group CFO said, "The company is fully geared up to capture additional opportunities in the infrastructure sector."



"Our relationship with Sandvik goes back a long way and I can honestly say that the Sandvik roadheaders have really met our needs: they are powerful, robust, and energy-efficient. Combined with Sandvik's comprehensive knowledge in tunneling, excellent service and solid technical support, I don't think one can find a better solution in mechanical cutting."

SILVESTRE VILLA
Operations Manager
Lurpeko Lan Berezziak
Spain



Versatility with exchangeable modules

ICUTROC for low energy consumption

Understanding underground

For decades, Sandvik has worked with various tunneling methods at customer sites around the world, creating expertise that results in intelligent cutting-edge technology. As the only manufacturer with its own underground R&D center at the factory, Sandvik continues to be the clear forerunner in tunneling equipment industry. Always striving to serve you with the best possible solution for your application at hand.

Scan the code and learn more about Sandvik in Tunneling.



www.construction.sandvik.com



Company	July	August	Change (%)
Aecom (NYSE: ACM)	32.26	35.08	▲ 2.82 (8.74)
Atkins (LSE: ATK)	1295.00	1300.50	▲ 5.0 (0.39)
Balfour Beatty (LSE: BBY)	221.20	238.60	▲ 17.4 (7.87)
BASF Global (XETRA: BAS)	83.66	74.34	▼ 9.32 (11.14)
Bekaert (BSE: BEKB)	27.46	26.96	▼ 0.5 (1.8)
Bilfinger Berger (DUS: GBF)	65.00	54.57	▼ 10.43 (16.04)
Leighton Holdings (ASX: LEI)	20.80	21.79	▲ 0.99 (4.76)
Costain Group (LSE: COST)	257.00	261.25	▲ 4.25 (1.65)
Ferrovial (MCE: FER)	15.39	14.86	▼ 0.53 (3.44)
Hindustan Construction Company (BOM: HCC)	39.20	36.05	▼ 3.15 (8.04)
Hochtief (XETRA: HOT)	62.02	57.72	▼ 4.3 (6.9)
Morgan Sindall (LSE: MGNS)	840.00	800.00	▼ 40 (4.76)
Sandvik (STO: SAND)	90.00	85.55	▼ 4.45 (4.94)
Shanghai Tunnel Engineering (SHA: 600820)	4.71	5.50	▲ 0.79 (16.77)
Strabag (LSE: STR)	21.58	20.42	▼ 1.16 (5.38)
URS Corporation (NYSE: URS)	56.06	58.29	▲ 2.23 (3.98)
Vinci (EPA: DG)	51.81	47.32	▼ 4.49 (8.67)

Prices are taken on the 12th of each month. NYSE is in USD. LSE is in GBP. STO is in SEK. BSE, EPA, MCE, STR and XETRA are in EUR. BOM is in INR. SHA is in CNY.

Hong Kong MTR names new projects director

Hong Kong Philco Wong has been appointed MTR projects director, with his responsibilities taking effect from 28 October. The incumbent, TC Chew, is retiring. For an easy transition, Wong has already begun work as 'projects director - designate'.

Wong has over 35 years of experience in business management, implementation and delivery of large-scale infrastructure projects in Hong Kong, the Mainland of China and overseas.

Since he joined the Corporation in November 2011 as general manager for the Shatin to Central Link, Wong has led his team in taking the SCL project forward through planning, contracts procurement to construction.

Lincoln Leong, deputy CEO of the MTR Corporation, "I would like to welcome Philco to the executive directorate team. His extensive experience in the construction and engineering

sector will be valuable in ensuring MTR continues to implement and deliver our five railway projects to high safety and professional standards.

"At the same time, I would like to thank TC for his dedicated contribution and commitment to the Corporation over the past several years, taking our railway projects through milestone after milestone."

Wong holds a BSc in Civil Engineering from the University of Manitoba in Canada, and a Masters in Construction Management and Engineering from the University of Toronto.

Alistair Kirk named High Speed Two programme and strategy director

Great Britain A spokesman for the High Speed Two (HS2) project announced last month that Alistair Kirk would become its programme and strategy director. Kirk will be responsible for the integration, planning and control of the overall HS2 Programme (both Phases One

and Two).

CEO - construction for HS2 Simon Kirby said, "Alistair joins us at an important time for HS2, as we continue the progress from development to delivery. Putting in place the right systems, controls and rigours in our planning is essential to ensure that we build HS2 on time and on budget. Alistair has an excellent track record across the defence and rail sectors. Moreover, his Middle East experience, where transportation is being heavily invested in to stimulate growth and act as a catalyst for change, will also be particularly relevant to helping ensure we deliver the wider benefits of the HS2 programme."

Kirk added, "I'm delighted to be joining Simon and the HS2 team at an exciting and pivotal point on the Programme. The opportunity to help build on the platform for success of such a strategically important Programme as HS2 is huge professional incentive for me.

Moreover, HS2 will provide similar opportunities for a

host of other engineering and programme management staff over the coming years. HS2 - amongst other major projects - will be a programme the UK transportation industry will be rightly proud of."

Alistair joins from EC Harris, which is part of Arcadis, one of the leading global transportation consultancies, where he led its infrastructure business in the Middle East, involved in developing Arcadis's view on the requirements for the new multi modal transportation system in Jeddah, Saudi Arabia.

MTR revises XRL cost projection

Hong Kong The MTR Corporation confirms it has recently completed a review of the Hong Kong section of the Express Rail Link Project's cost. The latest estimate puts this part of the project at HKD 71.52bn (USD 9.23bn). The figure is based on a revised end date of 2017.

An MTR spokesman said, "It should be emphasised that the Government continues to review the latest estimated cost and the Corporation will be cooperating to provide the additional information requested to assist the Government in its assessment."

Trading site turns 10

Germany Tunneltrade has celebrated its tenth anniversary. The company is an "online tunnelling portal" that allows companies to trade unused equipment, as well as search for personnel.

Co-founder Frank Schwarzer said of the company's formation: "We realised that there was probably an idle capital value amount to hundreds of thousands of Euros in medium sized construction equipment. And there was a high market demand for used machinery, particularly in Eastern Europe."



WHEN SHOTCRETE STABILIZES SLOPES. THAT'S BUILDING TRUST

SAFETY AND CONTROL ON A NEW LEVEL

The Aliva® Converto spraying device has been especially designed for hand-operated dry and wet shotcrete or mortar applications. The new key feature, in addition to its advanced design, is its unique new water ring system. The yellow water ring is suitable for dry spraying and the red water ring for wet spraying. By simply changing the water ring, no tools necessary, converting from dry to wet spraying is quick and easy. Consequently, the system for both spraying applications is the same.

SIKA SCHWEIZ AG
Aliva Equipment
Tüffenwies 16
CH-8048 Zürich
Switzerland

Contact
Phone +41 58 436 32 22
Fax +41 58 436 41 40
www.aliva-equipment.com
aliva.equipment@ch.sika.com



BUILDING TRUST





Terratec announced two breakthroughs on Delhi Metro contracts it was chosen to supply (see page 7). Pictured is the geology through the TBM cutterhead, which on one of the drives approached 200MPa

Cutting under the dense urban environment of Rio de Janeiro's southern and western sprawl is calling for a mix of measures, from drill and blast with shotcrete lining, to segmentally lined TBM drives. The mixed ground showed its complexity with a sinkhole earlier this year, but careful monitoring and quick response is keeping the project on track for the 2016 Olympic Games. Technical journalist Rhian Owen reports

A 16km metro line aims to remove 2,000 cars per hour during peak traffic and carry some 300,000 passengers a day, easing the strains of growth in the north and west districts of Rio de Janeiro. A complex array of construction methods and technologies are advancing the construction of the line beneath the densely populated favelas. While above ground a mix of retaining walls, bridges and at grade construction methods are driving the line through the varied topography.

Lúcio Silvestre, contract director of the building consortium Consórcio Construtor Rio Barra, responsible for the construction of Line 4 connecting Barra da Tijuca and Gávea says: "This is a highly complex construction project with cutting edge engineering solutions.

"The main challenge is to develop geotechnical models for underground works, while combining logistics and community relations, so as to avoid inconvenience in the daily life and routine of the surrounding population."

MANAGING INCONVENIENCE

Projects in densely populated areas often face two major challenges. First, how to undertake a major construction project without bringing the city to a standstill by flooding the streets with site equipment and materials movements. Second, and a challenge particularly difficult for Line 4, how to minimise the impact on surrounding buildings.

RIO REALISED



The project

Tunnels of Rio de Janeiro Subway Line 4 are built using two different construction methods: NATM and TBM. The subway will cover 16km from Barra da Tijuca in the west portion of the city, to Ipanema in the south

Started in June 2010 in the western neighborhood Barra da Tijuca, the tunnel boring operations by June this year had covered more than 8,000m between Barra and Gávea. Over this stretch, the boring operations are carried out using NATM – drill and blast, with controlled blasting. This method is suitable for rock boring, and consists of lining walls and arches with rock bolts, wire mesh and shotcrete, advancing while controlling deformation.

On a daily basis, blasting is monitored by seismographs to control vibrations and monitor noises and building settlements, in addition to instrumentation and previous assessments of the surrounding buildings.

This method was employed in the largest rock-excavated twin-tunnel connecting subway stations in the world, covering a stretch longer than 5km, from Barra da Tijuca to São Conrado.

From Gávea to Ipanema, the tunnel is being bored by TBM, with 2,700t, 120m in length and 11.5m in diameter.

The TBM is building subway tunnels between the stations General Osório (Ipanema) and Gávea, causing a smaller impact on the surface areas.

This construction method is best suited to the geology of Rio's south portion, consisting of sand, rock and water.

Rhian Owen

As a journalist and technical writer Rhian began working with *Tunnels* in 2011



The Rocinha favela, a 1940s and 50s slum now home to some 70,000 inhabitants in an area of just 1.43km², occupies an area of hills and valleys directly above center of the tunnel route. The houses are poorly constructed and as high as eight stories in some parts. A landslide in 2010 warned engineers of the weakness of the geology to be cut through. The lack of sewerage systems has further weakened the 8m of fractured rock and up to 15m of soil cover.

Through this section the tunnels will be mined by drill and blast. A wide range of monitoring solutions have been employed to give early warning of blast vibrations breaching the 6mm/s limits or ground movement putting the buildings at risk of damage.

Repression pins, piezometers, seismometers and tassometers are used to monitor at the moment of detonation and some 50 homes are monitored daily with repression pins. Seismographs and geophones are used to monitor vibration from the blasting.

Along the drill and blast route the tunnels cuts through very old rock.

"In São Conrado and Barra da Tijuca, Biotite Gneiss and Augen Gneiss rocks were excavated. As Gneiss is a rock of metamorphic origin resulting from the deformation of sediments and/or granite, it can be seen right at the entrance of the Barra tunnel under the Focinho do Cavalo Hill. That is the longest rock-excavated two-way tunnel connecting subway stations in the world, with 5km of length. Biotite Gneiss and Augen Gneiss are the main types of rock that also make up the Sugar Loaf, for



Above: Aerial view of Ipanema Beach

Below: Figure 1, Project alignment map laid over satellite image

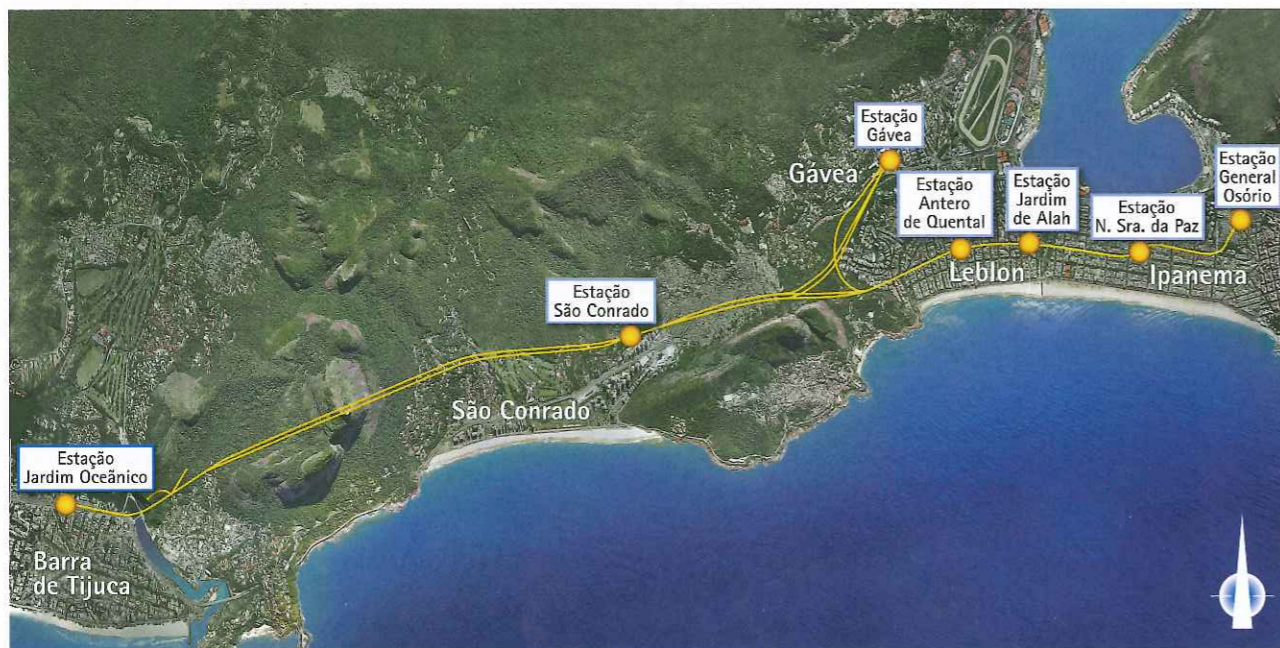
example. These rocks are from the Neoproterozoic era, aged 541 million to one billion years. It is so old, that the continents had not even been formed yet. The same type of rock can be found on the land where the Gávea Subway Station is being excavated."

The drill and blast sections have made steady progress, advancing an average of 4m per day, which now have more than 8,000m of twin bore tunnel with an area of 35m². "Excavation works progress according to the Bieniawski Rock Mass Rating, adopted in the design of rock excavation works to assess rock characteristics and determine how much it can be gone forward at each blasting," says Silvestre.

There are typically two detonations per day. Seven jumbos spend an average of two and a half hours to drill 71 holes, 13 of them pilots and the rest set over the usual 35m² cross section. Each blast will advance some 3.5m. Some 100m of muck is removed by nine excavators. Three eight hour shifts work the excavation 24 hours a day.

The tunnel is supported by arches with rock bolts, wire mesh and shotcrete.

Silvestre says, "The biggest challenge we have been facing are the logistics conditions, as we need to work in urban areas with large pieces of equipment, and carrying out controlled blasting in order to minimise any impacts to the buildings and traffic, and very few open areas next to our work sites."



"Supporting work sites were set up at strategic spots for the smooth progress of the work and less impact on the surrounding areas. Traffic studies and special traffic operations supported by Rio's city government minimised the effects of temporary road changes. At the squares of Ipanema and Leblon, in the south, where two subway stations are excavated, recreational areas and senior workout facilities were maintained throughout the construction period."

TBM DRIVE

On the Barra da Tijuca to Ipanema stretch of the drive, the ground is made up of rock and saturated sand with a high water table. "Probing studies, geological surveys and the subsoil tests conducted before constructions commenced showed that the TBM is the most suitable and safe set of equipment to perform this type of engineering work in the south of Rio de Janeiro, a densely populated area," says Marcos Vidigal, contract director of building consortium Line 4 Sul, responsible for the construction of Line 4 connecting Ipanema and Gávea.

The Herrenknecht TBM cutting Rio de Janeiro's underground is an EBPM. Weighing 2,700t, 120m in length

This is the largest piece of construction equipment ever used in Latin America

1bn

The age of the geology in years. It is so old, the continents had not yet been formed



Project players

The concessionaire Rio Barra is responsible for Rio de Janeiro Subway Line 4 project and is made up of two construction consortia: the Construction Consortium Rio Barra, which is building the Barra da Tijuca – Gávea subway stretch, including the subway station. The consortium is made up by Queiroz Galvão, Odebrecht Infraestrutura, Carioca Engenharia, Cowan and Servix; and Consortium Linha 4 Sul, which is building the Gávea – Ipanema subway stretch. This consortium is composed of Odebrecht Infraestrutura, Queiroz Galvão and Carioca Engenharia.



by 11.5m in diameter (as tall as a four-story building), this is the largest piece of construction equipment ever used in Latin America, according to the operators, and the biggest one ever used in subway constructions in Brazil.

While excavating, the TBM deploys the concrete rings that line the tunnel. The ring moulds were also manufactured in Germany by Herrenknecht. Made of steel, each mould section makes one ring section and each ring is made up of eight parts. The plant has five sets of moulds, each with eight sections, and the concrete rings are produced in a carousel system, which is similar to an auto assembly line: each mould has a dedicated worker monitoring it.

Once they leave the mould sections, the ring sections are lifted by vacuum

EPBM operation

The TBM that is operating in Rio de Janeiro's underground is an EPBM. The reinforced concrete rings are installed within the shield's protective housing. For tunneling with a shield in unstable soils, the loss of stability on the tunnel surface is offset by the generation of support pressure.

With an EPB, adjusting the speed of soil removal excavated by the cutting wheel is used to support the tunnel surface. To reach a balanced condition, the support pressure is transferred to the soil by hydraulic cylinders resting under the mounted rings, thus avoiding uncontrolled penetration. The amount of soil removed from the excavation chamber is regulated by the rotation speed of a worm screw, which is set to the advancing speed.

In the front section of the backup, the ring segments are raised one at a time by a transfer hoist. The hoist carries them to the segment feeder and transports them to the front of the tunnel. During this process, the excavation team are protected by the shield housing against earth pressure and water that may come from the water table. The ring sections are installed side by side, alternately. The tailskin is equipped with a circular seal — this seals the shield steel housing and the segmented ring, preventing a loss of pressure in the face. The annular gap between the exterior contour of the lining segments and the soil is continuously filled with grout injected from the tailskin injection holes or ring segment to seal the tunnel lining and stabilize it.

At each forward move made by the shield, the backup is pulled on wheels mounted on the tunnel rings. The steel frame also houses the hydraulic power units, pumps, electrical switchboards, ventilation systems, laser navigation instruments and soil conditioner storage tanks. It also houses logistics solutions to deploy the segmented rings and remove excavated materials.

As soon as the first sinkhole gap was found, the area was blocked off and excavation suspended



Promat

World Class Tunnel Fire Protection

Promat are the world's largest dedicated manufacturer of passive fire protection materials and global leaders in the Fire Protection of Tunnels, providing fire protection solutions to many of the world's largest tunnel projects.

Since the 1960's Promat materials have protected more than 190 tunnels using PROMATECT® boards. More than 1.4 million m² of tunnel linings have been protected using our spray applied systems.

www.promat-tunnel.com

an etex company

KORALM-TUNNEL (AUSTRIA)

Material Handling for Tunneling and Quarries

www.agir-aggregat.com

Safety Driven. Pure Performance.

Tyco offers a complete fire protection solution to safeguard the infrastructure of tunnels; whether it be rail, road or underground constructions, Tyco has expertise protecting some of the longest and most challenging tunnel projects in the world.

From detection to suppression, Tyco's technologically advanced Tunnel Fire Protection Solutions have been tested and approved by industry standards to ensure efficient, effective protection every time.

The Tyco Tunnel Fire Protection System now features the extended coverage offered by the TN-25 Nozzle, a specialized open nozzle which delivers efficiency, simplicity and pure performance by using less piping material - significantly saving costs, reducing installation and maintenance time whilst improving coverage.

Visit www.tfpemea.com/tunnelfireprotection for more details.

tyco
Fire Protection Products

Safer. Smarter. Tyco.™

©2014 Tyco Fire Protection Ltd. All Rights Reserved.



hoists up to a curing tunnel heated at a temperature ranging from 40 to 50 degrees. They are left there for five to six hours to speed up curing. Once the ring sections leave the curing tunnel, they are taken to a storage facility. They remain there for about 28 days to complete the curing cycle.

Vidigal says "The machine began operations in December 2013 and tunneled about 400 meters. In this construction project, the plans are to excavate 15 to 18m on average per day once the equipment is operating full steam ahead at a speed four times faster than the method previously used in Rio.

SINKHOLE

In the early hours of 11 May 2014, two sinkholes appeared on Rua Barão da Torre in Ipanema, where the TBM was excavating. Vidigal explains, "The outcome of the analyses of soil settlement that occurred in the morning of May 11 at Rua Barão da Torre in Ipanema shows that the incident was caused by an abnormal and specific behavior in the fractured rock face during the excavation of the subway tunnel in that street. The rock was dismantled and affected small neighbouring blocks, thus causing decompression of the soil. The process then evolved up to an area of sandy soil, and on to the surface."

The study also shows that four factors were at play in limiting the impact of incident: the excavation method, pretreatment of soil, monitoring of the ground and surrounding buildings' stability, and the prompt and efficient deployment of the Contingency and Emergency Plan.

"As soon as the first gap on the surface was found, the area was blocked off, excavations were suspended and it was found that there was no risk to the foundations of the surrounding buildings, as it was a localised incident. Once the area was blocked off, water and gas services were stopped and the holes



Top: Work underway on Oceanic Garden Station

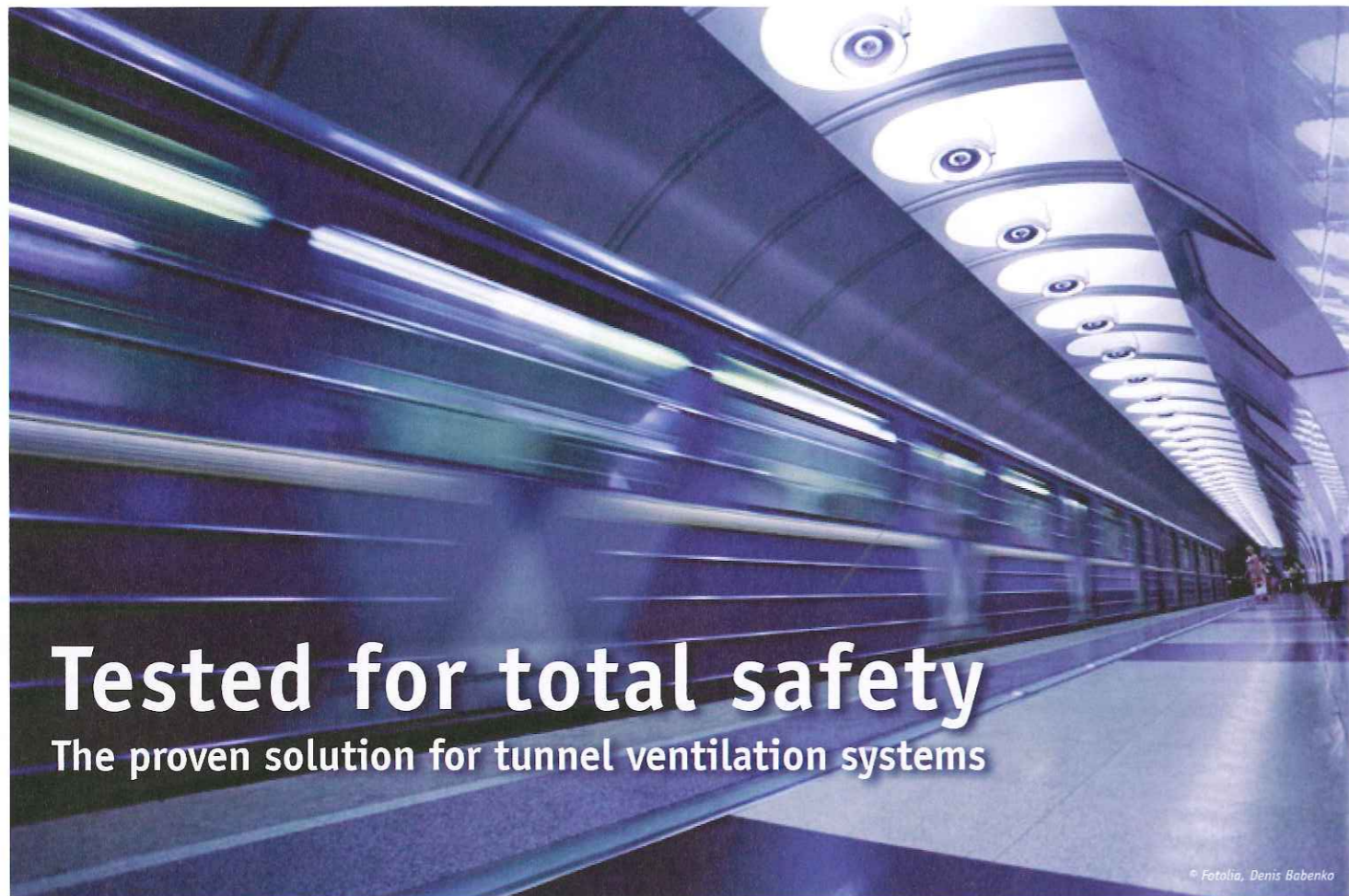
were filled with concrete.

In a construction project of this size, the buildings surrounding the excavation of tunnels and stations are permanently monitored. The buildings receive instruments (settling pins and inclinometers) to monitor how buildings behave before and during construction works. The results from these instruments are within the expected limits and the buildings are not at risk."

The project maintains that the use of TBM is the "most suitable and safe piece of equipment for tunnelling the subway that will connect Ipanema and Gávea."

Metro Line 4 is expected to go into operation in the first half of 2016

www.tunnelonline.info



Tested for total safety

The proven solution for tunnel ventilation systems

© Fotolia, Denis Babenko

TROX tunnel dampers for underground transport systems

- 4 hour fire integrity rating
- Class beating smoke isolation
- Smoke control operation at 400°C for 2 hours
- Robust design for 6kPa pressure differential
- Extensive worldwide application experience
- Worldwide project support



TROX[®] TECHNIK
The art of handling air

TROX Malaysia Sdn. Bhd.
20 Persiaran Bunga Tanjung 1
Senawang Land Industrial Park
70400 Seremban,
Malaysia

voice: +60 6 6788 188
fax: +60 6 6788 288
<http://www.troxapo.com>

DOUSED BY DESIGN

Interest is rising in water mist spray for fixed fire fighting systems in tunnels. Report by Patrick Reynolds.

Patrick Reynolds

Patrick is a freelance technical journalist who has covered tunnelling projects worldwide and has a mining background

AN INCREASING trend in fire safety in tunnels is for active intervention using water mists, such as retrofitted on the Channel Tunnel undersea rail link between UK and France, and the Tyne Tunnels, and refurbished Dartford road tunnel, and is under development for the Stockholm ring road. ■

But water mist is only one of the key types of fixed fire fighting systems (FFFS), the others being deluge water spray, and foam.

FFFS is increasingly part of the discussion, and debate, to provide enhanced fire safety solutions in transport tunnels, notes Haukur Ingason, underground fire safety researcher with SP Technical Research Institute of Sweden. He adds that the take-up of FFFS has only really started to take hold in the last decade or so in Europe, most especially, and also North America, while it has a longer pedigree in Asia and Australasia in major road tunnels,

There is an observable tendency towards FFFS, says Armin Feltmann, sales engineer-tunnel systems with Fogtec "especially high pressure water mist systems".

He says there are increasing numbers of papers and presentations on this aspect of FFFS at conferences, and adds: "Some standards are now also acknowledging the compensation potential when installing FFFS into a tunnel."

FFFS IN CHANNEL TUNNEL

The 53km long Channel Tunnel suffered serious fire damage to stretches of its tunnel lining in 1996 and 2008. There were no fatalities or injuries, and everyone escaped by cross passage into the sealed Service Tunnel, the repairs needed to the running tunnels were both extensive and expensive. Transport capacity on the rail service was reduced for months, and so revenues too (see box).

"While the Service Tunnel has shown

The challenge was to prove to insurers that the system could protect infrastructure

itself to be extremely effective in terms of supporting human safety in fires, the running tunnel damage and insurance cost was huge," says John Keefe, spokesman for Eurotunnel, the owner and operator of the UK-France fixed rail link. "Fire-fighters were pretty powerless to intervene in the confined space once the fire took hold."

Insurance paid for all repair costs – EUR 250M (USD 334M) to recover from the 2008 fire. Annual premiums then trebled from the previous level of EUR 10M (USD 13M). "A significant increase," says Keefe.

He says the challenge was to prove to insurers that the system could protect infrastructure, and so reduce risk and premiums. After the 1996 fire, the emergency rules changed to make trains stop in the tunnel for evacuation at a cross passage to the Service Tunnel. But the question remained of how to overcome the potentially costly problem of infrastructure damage in any future incident.

Eurotunnel's solution was the 'SAFE' (Station Attaque FEu – or, fire attack station) concept, which involved building insitu FFFS "stations" in the tunnel for suspect freight trains to reach and stop. In effect, a train would go to the fire fighting resource rather than vice versa – and be able to reach the SAFE station within 15 minutes.

"The SAFE stations are in place. They work," says Keefe. "We've never had to use them – which is good as their purpose is against an eventuality we don't want to happen."

In each running tunnel are two SAFE stations, built one third of the way from the portals. The symmetry of the layout in the twin tunnels means they are effectively pairs, one each side of the Service Tunnel. The retro-fitting work to install the system was undertaken from within the Service Tunnel, which holds the power and pump installations, and from where a series of water pipes link through to the running tunnels to feed the main distributor pipelines.

Patented Fogtec equipment is part of the solution employed in the SAFE stations within the overall Eurotunnel design.

Below, left: Water-mist spray to prevent Channel Tunnel infrastructure fire damage

PHOTO: EUROTUNNEL

Below, right: Fire damaged freight train removed from Channel Tunnel in 2008

PHOTO: EUROTUNNEL



"Most of the train is left untouched," says Keefe.

Research and proving tests were undertaken in a special fire tunnel at San Pedro des Anes, in Spain, and then a water-mist only test in the Channel Tunnel, all of which helped to convince Eurotunnel and insurers of the value of the SAFE system. The tests involved a pipeline high in the tunnel with nozzles 3m apart to deliver water under 115 bar pressure.

Development work was done over 2009-10, and installation got underway in 2010. Completed, Eurotunnel saw its annual insurance premiums drop to about EUR 11M (USD 14.7M). As a result, one year's saving in premium paid for the EUR 20M (USD 26.7M) design and build of the SAFE system, and will keep down future costs.

No one else has taken up its SAFE concept, he says, although many organisations visit the Channel Tunnel. Keefe notes that the infrastructure is "unique in the rules that govern it," and that the third tunnel, the Service Tunnel, was "vital to retrofitting".

TECHNOLOGY, RELIABILITY AND TRADE-OFFS

FFFS has a history of controversy over its application in tunnels, notes SP's Haukur Ingason, who led a cross-

Others involved were Fogtec's subsidiary Acis, consultancy IFAB Institute for Applied Fire Safety Research, and contractor Spie.

Keefe says the concept is to produce a high pressure, micro-mist that starves the fire of oxygen. The choke off is achieved by the thickening steam cloud as water evaporates, and in the process helps reduce heat radiation from the blaze. The fire is doused until emergency services get in and put out a blaze or investigate.

Specific nozzles come are activated in response to monitoring data from infrared detectors, and therefore only a few of the 29 sections – each 30m long – that make up the full length of a SAFE station are switched on.

Above: Retro-fitted SAFE water-mist spray system in Channel Tunnel

PHOTO: EUROTUNNEL

board Swedish underground transport fire safety study, called 'Metro', over 2009-12.

Speaking recently at the 7th International Conference on Tunnel Safety and Ventilation 2014, in Austria, Ingason discussed what he sees as an "upcoming controversy", in the question of technical trade-offs.

The question surrounds whether employing FFFS would allow for offsetting, in effect – allowing some reduction in other types of protective factors in tunnel, such as the design fire load for the ventilation system, protection for the structural lining, or even perhaps wider spacing for escape exits, according to a conference paper co-authored by Ingason (Ingason and Li, 2014).

Ingason notes the absence of guidelines and standards for evaluating the effects of the technical trade-offs. He recommends that a reliability analysis of the FFFS and other systems be done before trade-offs are made.

To meet reliability needs by ensure equipment has high availability, Feltmann emphasises that performance targets are met by studies in the initial stages of design; the studies are

Before the SAFE system

The two fires that damaged the Channel Tunnel left Eurotunnel with major, and expensive, infrastructure repair works to execute, and do so against the clock as each day the rail link was left to operate under reduced capacity. Its approach to handling the tunnel repair works was markedly different in each case, and they took notably less time to complete after the second fire incident, all due to lessons learned and applied.

Following the first fire, in 1996, Eurotunnel found severe damage to the concrete lining along a stretch of the central section of the South Tunnel. Temperatures in the fire had reached 700 to 800°C, and over hundreds of metres rebar was exposed – with an average loss of up to 200mm thickness of ring thickness. There were spots where the concrete was totally gone, leaving only the steel cage and sight of the grouted annulus.

The fire damage in 2008 happened in the North Tunnel, approximately 11km from the French portal. The lining once again suffered significant damage. In both cases, the freight passengers – in a special car near the front of the train – were evacuated safely along with the crew into the Service Tunnel via a cross passage, and sealed doors.

In both cases, the repair works removed parts of the lining too weak to remain, and then employed some steel mesh placement along with sprayed shotcrete. However, whereas the first repair works took place over many months (January-May 1997), on the second occasion they were completed in a fraction of the time.

On the first repair project, the civil works were performed using a single train parked insitu and the section of tunnel sealed by bulkheads; access was through the Service Tunnel. However, on the second project a portal was out of operation and could be used for direct access using works shuttle trains. In the damaged section, gantries and crews were deployed in a more intricate, phased series of rolling works, allowing multiple activities to be underway.

Eurotunnel said at the time that the almost 'industrial' approach to the repair the second time round resulted, in part, from its team having far more experience by then in maintaining the infrastructure.



Reliability, Availability, Maintainability and Safety (RAMS), he says. Feltmann adds that high availabilities are founded upon selecting proper components – both technology and materials.

With respect to Fogtec's involvement in the Channel Tunnel's SAFE system, Feltmann describes the need to ensure components can deliver the lowest maintenance needs – being "basically maintenance free" – and are such the likes of welded stainless steel pipes, and passive stainless steel nozzles without moving parts. Redundancy in pump units also can be sought, and spares for normal consumables should be stocked on site.

Section valves are the 'most critical' components in the FFFS and would be the only 'active' part needing regular testing, says Feltmann. He adds that some have been developed to be tested remotely – and so a tunnel closure or part closure is not needed, and traffic is not interrupted. Further advantages, he points out, include speed of testing and lower costs in doing so, and that economic benefits come from the regular testing regime, leading to high availability of the component.

Although there is no specific and universal guidance for FFFS, then based on research done so far, given a satisfactory reliability analysis during design development on a transport tunnel project, Ingason and colleagues propose some suggestions around fire load and ventilation, lining protection, and exit intervals.

In looking at fire loading for inputs to the technical trade-offs analysis, Ingason also discusses full-scale tests carried out by SP and Trafikverket (Swedish Transport Administration) at Runehamar tunnel, in late 2013. The tests are described (Ingason, Li, Appel and Lundstrum, 2014) given to another conference, the 6th International Symposium on Tunnel Safety and Security, held earlier this year, in France.

The tests were developed by the two organisations working in collaboration with Swedish consultancy Brandskyddslaget. They were undertaken to examine water deluge systems for limiting the size and spread of a fire, and so allow for evacuation in congested traffic, and were based on simple, low pressure dispersion from pairs of nozzles on a pipeline. The system for the full-scale tests in the 9m wide Runehamar tunnel was established in preparatory lab tests. The water supply for emergency services is integrated to FFFS. Estimated costs, including maintenance, are about half that of traditional deluge systems, the researchers said.

Among the conclusions from the Runehamar tunnel fire tests, the researchers say that early activation of the FFFS is vital, although state in their paper that the system has "a sufficient safety margin to allow delayed response while retaining the ability to fight the more severe fires produced by such a delay." But further research is advised, not least to look at the extra smokes and toxic fumes released by not having the FFFS activated early enough.

Trafikverket, which is responsible for both road and rail infrastructure in Sweden, has the fire safety tests and planning underway as part of developing Stockholm's new ring road system, much of which will be underground – in tunnels up to an average of 15m wide. The fire safety tests were part of a strategic EU transport initiative, which provided a grant towards the work as part of developing the Stockholm bypass.

Also on possible trade-offs – or compensation potential, as called by Feltmann – the recent Safety of Life in Tunnels II (SOLIT-2) research project had this as one of its points of study for road tunnels. The SOLIT-2 latest research was reported in November 2012, and includes reference to earlier guidance, such as UPTUN, and also references Eurotunnel's SAFE system.

The SOLIT-2 project says: "Practically, this means that investing in water mist fire fighting systems may possibly allow for a higher safety level and savings in conventional equipment

Left: Repairing tunnel lining in Channel Tunnel after 2008 fire
PHOTO: EUROTUNNEL

Right: Removing concrete in Channel Tunnel damaged by fire in 2008
PHOTO: EUROTUNNEL



at the same time. In the overall balance over the life cycle, costs can thus be reduced."

Feltmann explains the further importance of SOLIT-2 in fire safety design by explaining that it is used – notably Annex 3 – in many tender documents, such as recent projects like City Tunnel Bregenz, Arlberg tunnel, Heathrow, and fire tests for the Mont Blanc Tunnel.

SOLIT-2 guidance also include Annex 7 to provide an overview of how fire tests should be carried out, and this helps to determine the FFFS layout to be tested, including flow rates, pressure, distance, and type of nozzles, he adds.

The SOLIT research was founded, and is funded, by Germany's Ministry of Economics and Technology. Those involved in the research include Fogtec, research association Stuva, consultancy Bung, Ruhr University Bochum, the state of Saxony-Anhalt's fire institute, IFAB, and TUV Sud Rail.

References

- Ingason, H; and Li, Y.Z.; *Technical Trade-Offs Using Fixed Fire Fighting Systems* – 7th International Conference "Tunnel Safety and Ventilation" 2014 in Graz, Austria;
Ingason, H; Appel, G; Li, Y.Z.; Lundstrum, U; and, Becker, C; *Large Scale Fire Tests with a Fixed Fire Fighting System (FFFS)* – 6th International Symposium on Tunnel Safety and Security (ISTSS), 2014, in Marseille, France;

The Greatest Advance in Heat Detection in Over 70 Years . . .

The New FiberSystem 8000

Can your detection system do this?

- Provide continuous temperature monitoring
- Graphically display temperature profile, fire size, and direction of spread
- Provide 256 zones of detection with a single linear sensor for up to 5 miles (8km) of protection
- Offer multiple alarm initiating criteria by zone
- Provide complete immunity to RFI and EMI interference

If not, you must see the new FiberSystem 8000 Fiber Optic Heat Detection System by Protectowire. Advanced fiber optic technology provides increased detection capabilities and rugged reliability for every type of commercial and industrial application.

"See the Light" now at protectowire.com, or contact your nearest Protectowire distributor.

Heat Detection Using the Speed of Light!



PROTECTOWIRE
FireSystems

The Protectowire Company, Inc.
60 Washington St, Pembroke, MA 02359-1833 U.S.A.
781-826-3878; www.protectowire.com
An ISO 9001:2008 Registered Company

Improve 24/7 Traffic Control Under the Darkest and Brightest Conditions with FLIR Thermal Imaging



Sun glare, shadows, darkness, and wet streets often pose problems for standard video cameras, confusing software that controls traffic lights. FLIR high-performance thermal cameras help overcome those challenges, providing more reliable detection of vehicles, cyclists, and pedestrians for smoother flow and greater safety day and night.

- Sees in total darkness and bright daylight in practically any weather
- Serves as a simple plug-and-play replacement for visible cameras
- Extremely affordable and easy to use

See how thermal imaging
keeps traffic flowing at
www.flir.com/its-tunnels



The World's Sixth Sense™

BTS CONFERENCE AND EXHIBITION 2014

BTS at a glance

When: 23rd - 24th September 2014
Tuesday 23rd September: 09:30 - 18:00
Wednesday 24th September: 09:30 - 16:30

Where: QEII Centre, Broad Sanctuary, Westminster,
London, SW1P 3EE

What: A two day focused conference, covering a host of topics and free entry to the UK's largest dedicated Exhibition for the tunnelling professional, which runs alongside the conference

Conference cost:

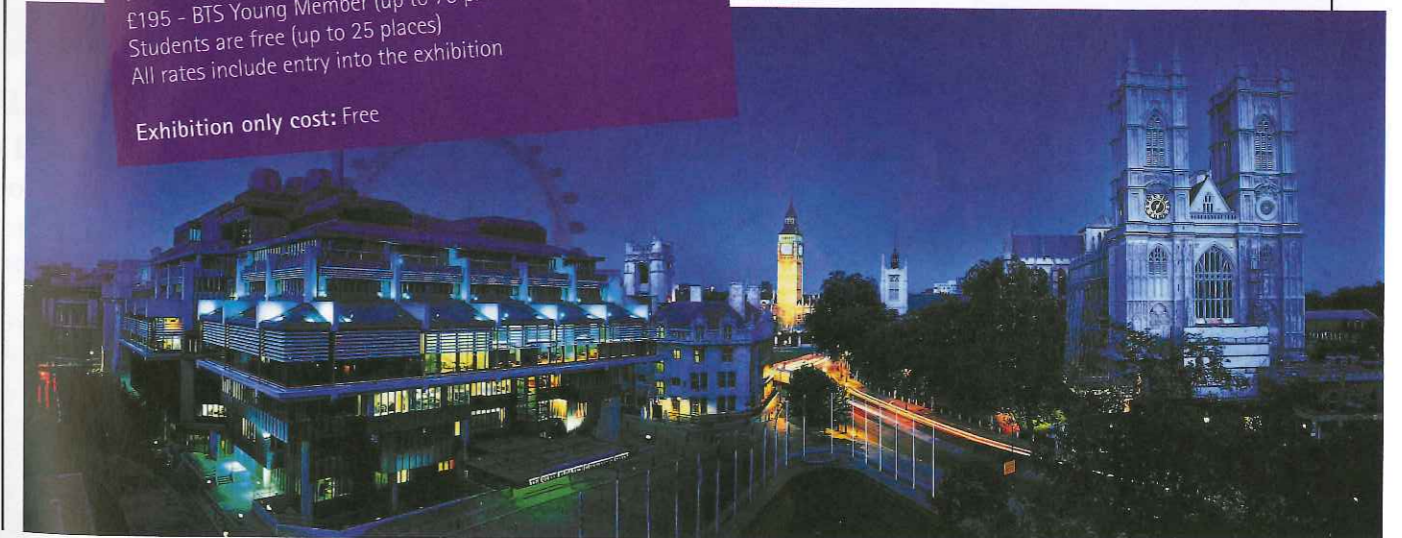
- £445 - BTS Members
- £495 - Non-members
- £195 - BTS Young Member (up to 75 places)
- Students are free (up to 25 places)
- All rates include entry into the exhibition

Exhibition only cost: Free

THE BRITISH Tunnelling Societies Exhibition and Conference returns once more to the heart of London on the 23-24 September 2014 at the QEII Centre, Westminster.

The BTS Exhibition and Conference has not only risen to become the UK's largest tunnelling and excavation event, it is the only show supported by the British Tunnelling Society.

This exclusivity, alongside the success of the 2013 event, makes BTS 2014 an essential meeting point for tunnelling professionals involved in the design, management and maintenance of today's expanding tunnelling and



BTS evening meeting

One highlight not to be missed will be BTS monthly talk, which for the convenience of attendees will also be given at the conference centre. This month it will be given by Andy Alder (Crossrail / CH2M Hill), Adrian St John (BFK JV), and Stephan Fleischmann (BFK JV) on the Crossrail Western Tunnels project. Work on Crossrail's Western Tunnels includes 13.6km of TBM bored running tunnels from Westbourne Park to Farringdon, Sprayed Concrete Lined station tunnels at Bond Street and Tottenham Court Road Stations, and an emergency shaft and tunnel crossover at Fisher Street. The tunnels were mined under the west end of London beneath a large number of sensitive buildings and close to a range of critical infrastructure assets. These tunnels were on the critical path of the whole Crossrail programme. This presentation will cover the whole development of the Crossrail Western Tunnels, from design, through procurement and to construction and successful completion. It will describe how the numerous technical challenges have been overcome, particularly control of settlement, and design and execution of major SCL station tunnels. The project management challenges will also be covered, explaining how the team maintained the programme through numerous contract and third party interfaces.

underground infrastructure.

The BTS Conference, which will run alongside the 2014 exhibition, will comprise of two days of highly technical and educational talks where industry professionals will learn, debate and challenge current and future tunnelling projects. If you live and breathe tunnelling and excavation and want to see it in action, there is no other place to be



Made by Macrete

Smoothbore Segmental Shaft Linings

2.44m up to 3.66m ID

Universal Segmental Shaft Linings

Bolt from the back or the front
4.00m up to 27.00m ID

Segmental Tunnel Linings

2.44m, 2.85m and 3.05m ID

Vacuflush™ Chamber

A unique waste water holding tank vacuum flushing system

Shaft Cover Slab Systems

Custom designed for your needs

Precast Culvert Systems

Minimum 1000mm custom designed for your needs

Jacking Pipes

Range from 600mm to 2100mm

Contracts recently supplied include:

- River Ribble & Preston 32 UIDs
- Crosby Vacuflush System
- Warrenpoint VwPS
- Gloucester FAS
- Todmorden FAS
- Dunfermline FPS



028 7965 0471 www.macrete.com

Develop the industry,
grow with us.



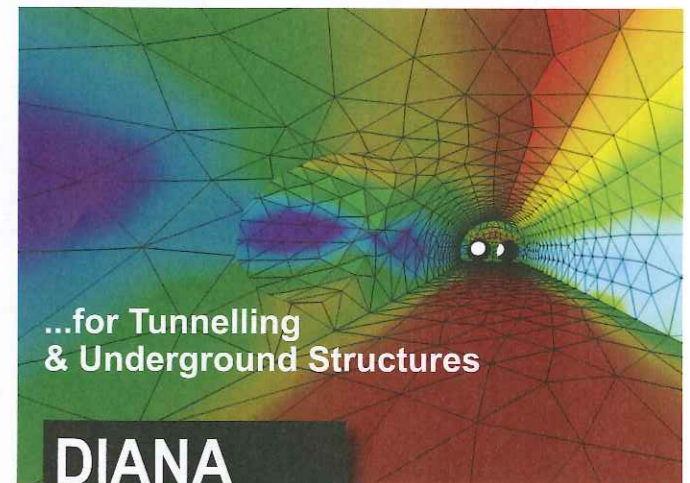
Alan Auld Engineering are opening a London office

in September and we are looking for **dynamic** and **innovative** engineers to extend our **collaborative** design approach to the capital.

There is a **unique opportunity to lead and grow** Alan Auld Engineering's **London office** for the right candidate. If this might be you, please send a covering letter and CV to the e-mail address below quoting TT01. No agencies please.



e-mail: HR@AlanAuld.com
www.AlanAuld.com



...for Tunnelling & Underground Structures

DIANA

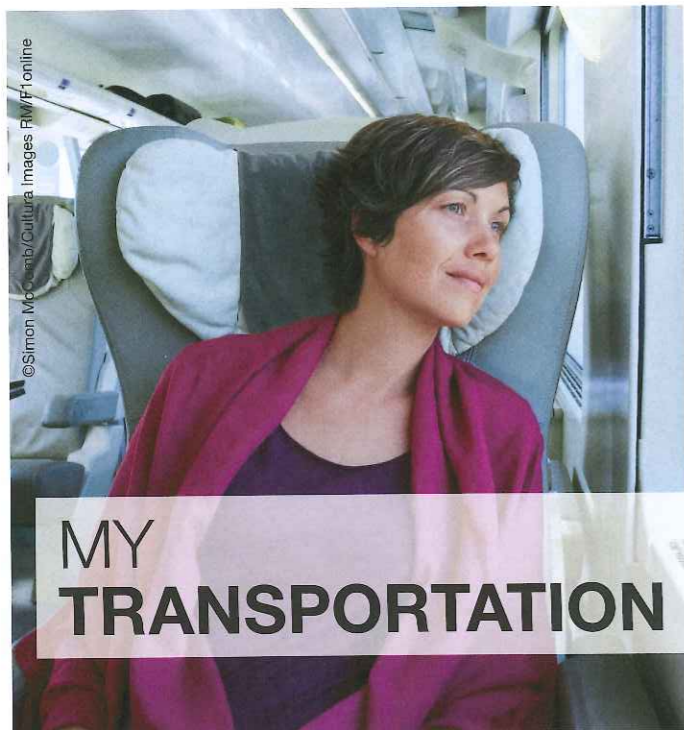
finite element analysis

Specialising in the analysis of new and existing structures, tunnels and linings under the effect of...

- settlement and additional loading
- fibre reinforced materials
- structural damage
- earthquake
- freezing
- flood
- fire

www.tnodiana.com





©Simon McComb/Cultura Images RM/Flonline

MY
TRANSPORTATION

OUR
ROUTE



Those who travel by train want to get to their destination fast, safely and without stress. That is why HOCHTIEF is building rail links throughout the world that bring people and regions together. One example is the Gotthard Base Tunnel which we built in two phases with four partner companies. The world's longest rail tunnel—57 kilometers in length—will link the towns of Bodio in Ticino and Erstfeld in Uri Canton and, from 2016, will halve travel time between Zurich and Milan. In this way every trip is turned into an exceptional experience.

CROSSRAIL C310

Geotechnical and tunnelling related specifics in urban tunnelling, and a river crossing with low overburden are covered in this BTS presentation on Crossrail contract C310, Thames Tunnel

THE CONTRACT C310 is part of the current biggest infrastructure project of Europe "Crossrail" which is a major new cross-London rail link project and comprises the construction of the North Woolwich Portal, Plumstead Portal and the twin tube Thames Tunnels with a length of approximately 2.6km. Two Mixshield TBMs (diameter 7.12m) are driving through differing challenging ground conditions (Thanet Sand, Gravels, Flint and Chalk) below the ground water table. The two tunnels are underpassing several listed buildings, sensitive structures, operational railway tracks with low overburden and close to existing subway tunnels in an urban environment. Several additional measures as compensation grouting, micro piles and an intensive monitoring have been carried out to ensure a safe tunnelling process. During the drive underneath the River Thames, the tunnels will only have an overburden of approximately 12m. The effect of pressure variation due to the tidal River Thames has to be taken into account for the control of the face support pressure. The excavated and the dissolved soil were pumped to a treatment plant where a dewatering process with filter presses was used with great success. After finishing the two main tunnels four cross passages were opened using a sprayed concrete lining. To reduce the water inflow in the chalk aquifer fissure grouting has been executed prior to construction of the cross passages.

PROJECT OVERVIEW CROSSRAIL

Project Crossrail
Crossrail is currently the biggest infrastructure project in Europe

which has been developed to serve London and the southeast of England. The project includes the construction of twin-bore tunnels on a west-east alignment under central London and the upgrading of existing National Rail lines to the east and west of central London. The new rail track, as shown in Figure 1, starting in Shenfield/ Abbey Wood in the east of London and ending in Reading / Heathrow Airport in the west of London, includes the construction of nine central area stations, providing interchange with London Underground, National Rail and London Bus services, and the upgrading or renewal of existing stations outside central London. Altogether there will be 118km of new rail tracks, including 42km of tunnels and 40 train stations. After completion in 2018, Crossrail expects 200 million passengers per year (Tauriainen, Rädle, Ingram 2013).

Contract C310 Thames Tunnels (bored tunnel drive H)
Hochtief Murphy Joint Venture (HMJV) is responsible for the construction of two tunnels underneath the River Thames with the contract name C310 Thames Tunnel. The contract C310 comprises the construction of the Plumstead and the North Woolwich Portal, as well as the twin bored tunnel with a length of approximately 2.6km. Contract commencement date was early March 2011 and in November 2011 the construction of the tunnel portal in Plumstead started. The main tunnelling works started in January 2013 and the anticipated completion of the tunnelling work including cross passages and pump sumps is September 2014. Completion

Below: Figure 1, Overview of the Crossrail project



Riku Tauriainen
Riku is project director for the Hochtief-Murphy joint venture on the C310 Thames Tunnel contract for Crossrail

Andreas Raedle
Andreas is the Hochtief-Murphy joint venture's technical and risk manager also on Crossrail contract C310

of the whole works is expected by mid June 2015. C310 is a challenging project, both technically and operationally, due to its location and difficult geotechnical conditions.

The two TBMs will drive through varying ground conditions (Thanet Sand, Alluvium, and Chalk) below the water table (see Figure 2). During the drive underneath the River Thames, the tunnels will have an overburden of approximately 12m. The effect of pressure variation due to the tidal River Thames has to be accounted for in the control of the tunnelling operations. The tunnel will pass underneath several listed buildings, operational railway tracks, utilities, close to existing subway tunnels and will pass through Woolwich Box Station (Tauriainen, Rädle, Ingram 2013).

GEOTECHNICAL AND HYDROGEOLOGICAL CONDITIONS

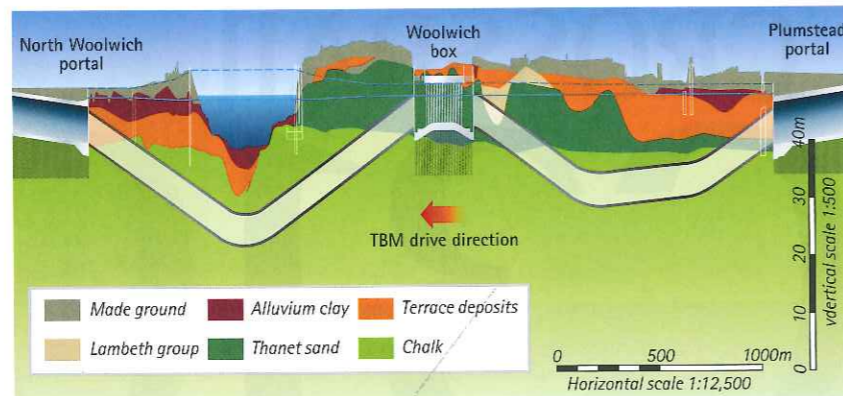
Geotechnical situation

The site geology consists of the Chalk group with intermediate flint layers overlain in parts by Thanet Sands and in parts by floodplain Terrace Gravels, Alluvial layers (Clay, Silt and Peat) and Made Ground.

Tunnelling started from Plumstead Portal south of the River Thames in the river terrace gravels which are typically described as medium dense to very dense, grey brown or dark grey, slightly silty, slightly clayey, fine to coarse sand and fine to coarse sub-angular to rounded flint gravel. The sand and gravel proportions varied from very gravelly sand to sandy gravel.

The underlying Thanet Sands were met shortly after TBM launch. These are predominately sequences of dense to very dense, fine-grained sands, with higher proportions of clay and silts in the lower part. The unweathered formation is grey to brownish grey, and at the surface it weathers to a pale yellowish grey. The genuine flint belongs to the basal Bullhead Bed which is a conglomerate comprised of rounded coarse flint gravels and nodular flints in a matrix of dark greenish grey, clayey fine to coarse grained sand.

In parts of the river, the Alluvium is non-existent and hence the chalk-gravel aquifer connected directly to the River Thames



Above: Figure 2, Longitudinal section of contract C310, Thames Tunnels

The chalk horizon will be met after 100m from the launch site and will lead to mixed face conditions. Chalk is generally considered to be a soft/weak rock, very pure white limestone formed from the skeletal remains of submicroscopic algae. However, unlike many limestones, chalk is very widespread as a consequence of its entirely planktonic origin. Two features commonly found in Chalk are flints and marl seams. Flint is a microcrystalline silicaceous rock that occurs as dispersed, usually black nodules or as tabular bands or sheets. Flints represent very strong, brittle inclusions in contrast to the comparatively weak host Chalk matrix. Marl seams are horizons with increased concentrations of clay.

Two different chalk layers were hit by the C310 tunnel, the Chalk of the Haven Brow Beds and the Cuckmere Beds. The Chalk is very weak at the top of the layer, highly weathered and described as low density white Chalk improving in both strength and density with depth. Generally the Chalk is described as medium density chalk.

Approximately 80 per cent of the tunnel length is located within the chalk horizon. Only 150m to 300m before reaching and after leaving the portals and Woolwich Box the tunnel face is located in the Quaternary and Palaeogene soils. (Crossrail, 2007)

Groundwater conditions

In the area of C310 the hydrogeology is controlled by two aquifer systems made up of the Upper Chalk and the overlying floodplain Terrace Gravels. Since the gravels or the Thanet Sands lie directly on the pervious chalk, the two aquifer systems are in hydrostatic contact and have achieved equilibrium.

On the south and north side of the River Thames the aquifers of Chalk, Thanet Sands and Terrace Gravels are sometimes confined by overlying Alluvium (clay, silt and peat). In parts of the river, the Alluvium is non-existent and hence the chalk-gravel aquifer is connected directly to the River Thames.

A response to the tidal motion of the River Thames was observed, depending on the distance to the river. The maximum groundwater level is set at 104.5m above tunnel datum (mATD) whereas the minimum is set at 96.5 mATD.

The variation of ± 4 m to the average groundwater level of 100.5 mATD can be found in close proximity to the River Thames. The rest of the tunnel alignment has a pre-set variation of ± 1 m. Based on this information Hochtief developed the water level diagram in Figure 3 and defined three design water levels which were used for the support pressure calculations. These water levels are not the water levels of the Thames but the expected pore pressure in the chalk/gravel/sand aquifer.

An additional item which needs to be considered in the calculations is the time dependence of the damping of the pore

pressure. In the boreholes adjacent to the river the measured delay was approximately 0.5 hour.

TBM TUNNELLING UNDERNEATH SENSITIVE URBAN STRUCTURES

Launching in close proximity of North Kent Railway Line

Directly after cutting through the diaphragm walls at Plumstead Portal for duration of approximately 36 calendar days the TBMs were excavating in Network Rail's zone of influence close/adjacent to operational North Kent Line, underneath White Hart Road Bridge and Cathedral Substation. In this area the tunnel cross section is located within Mixed-Face Conditions (Gravel, Thanet Sand and Chalk) with low overburden of approximately 7 to 10m for the first 150m of tunnelling.

Real-Time Monitoring devices consisting of ATS and prisms on the railway and hydrostatic levelling cells on the bridge and substation were installed. The HMJV monitoring system, Advanced Tunnel Drive Steering (ATDS), was collecting any movement and/or potential settlement on an ongoing 24/7 basis and showing the data in real time.

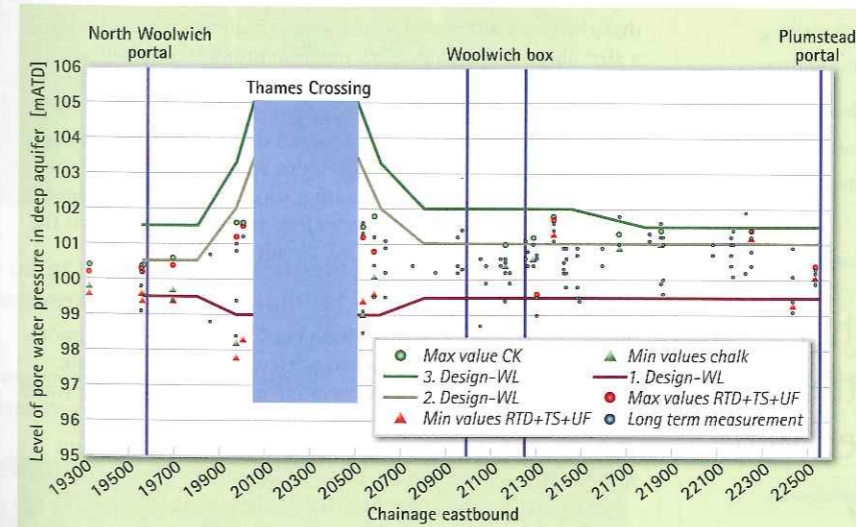
Underpinning White Hart Road Bridge

White Hart Road Bridge is located approximately 40m from the launching point of the TBMs. To mitigate possible settlements caused by the tunnelling operations of the closer passing TBM 1, the foundations of the bridge required supporting by means of underpinning.

To strengthen/support the foundation of White Hart Road Bridge, a micro-pile and soil anchor scheme was the preferred method for the underpinning of the bridge. The scheme comprised of a set of three piles at approximately 500mm c/c along the length of the abutment.

These sets consisted of two raking piles - supporting vertical loadings and one soil anchor - which were designed to control any subsequent horizontal movement. To ensure no load was transferred into the piles during the tunnelling operation, the piles were permanently cased to the invert level of the proposed tunnel, thus transferring the load of the bridge into the chalk strata below the tunnel invert.

The soil anchors were stressed to provide the required reaction force to prevent lateral movement of the bridge foundations. The ground anchors were de-stressed and removed as the tunnelling operations have been ceased; hence



Below: Figure 3, Diagram of expected pore water pressure in gravel/sand/chalk aquifer for support pressure calculation

they were classed as temporary.

During the passing of the first TBM, no significant movement of the bridge or its foundation was observed. All measured movements were less than 2mm, however the north eastern wing-wall of the bridge, which is not connected to the bridge itself, was noted to have settled 6mm during the time that the TBM was at a standstill at this location for more than 12hrs due to a grouting issue. The bridge was monitored with a number of hydrostatic levelling cells that fed real time data to ATDS so this movement could be observed and monitored in real-time by HMJV. This demonstrated that the employed scheme was effective and the correct chosen method.

Compensation grouting for Cathedral Substation

The existing building Cathedral Substation (Network Rail Substation) is located west of White Hart Road and north of the running North Kent Line. For Cathedral Substation the requirement for compensation grouting to prevent settlements caused by tunnelling is driven by the need to protect the highly sensitive equipment within the building. Movement criteria have been agreed with Network Rail and Crossrail after contract award.

The distance between the tunnel crown and the floor was only 6m and compensation grouting was designed for River Terrace Deposits and groundwater with three layers of TAM (tube-a-manchette). During installation of the TAM Drillings prior to tunnelling no settlements occurred due to the chosen drilling technique (duplex heading technique with full casing and subsequent immediate grouting of each hole) and the designed pre-heave of approximately 3mm have been achieved.

Both TBMs have successfully overpassed and by use of reactive compensation grouting the movements of the building maintained in the allowable limits (between +5 and -10mm).

TBM TUNNELLING UNDERNEATH THAMES RIVER

Tidal fluctuation

Tunnelling underneath the River Thames was one of the challenges of the TBM drive. The overburden to the river bed was minimum only 10 to 12m.

Due to the proximity to the sea, the Thames Water Level and therefore the adjacent groundwater level, is highly

www.tunnelsonline.info

A world of information fully archived and searchable at the click of a mouse



affected by the tides. The duration of one tide cycle is about 12 hours, meaning that two cycles with two minimum and two maximum peaks take place per day. Between low tide and high tide the Thames Water Level alternates over 8m, causing relevant face pressure changes of approx. 0.8 bar. Therefore the support pressure has to be constantly reviewed and adapted.

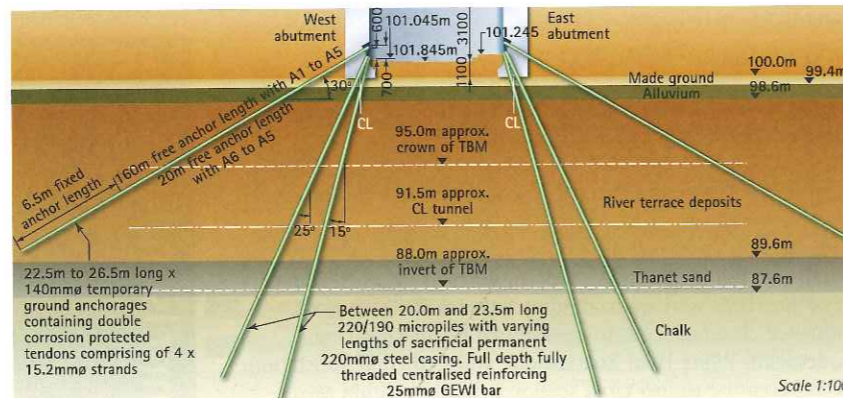
An additional item is the time dependence of the damping. In the boreholes adjacent to the river the measured delay was approximately 0.5 hour. This time effect will be covered by an increase of the pore water pressure by 2.5 m for low Thames Water levels and the damped value is used to calculate the corresponding theoretical support pressure.

Detailed operational tables for the supporting pressure for the regular tunnel drive were derived from the detailed calculations. For each ring position and respective tunnelmeter the corresponding pressures for the three different water levels have been compiled and interpolated between the calculation cross sections. Based on those tables an automatic calculation and correlation of the support pressure to the tide measurements (illustrated damped water level) within the TBM Data Process Management System TPC takes place and the theoretical support pressure is displayed.

The damped water level for the calculation of the theoretical support pressure is capped at a minimum of 99 mATD although the minimum design river water level is 96.5 mATD. The reason for this is to maintain a conservative assumption. During low Thames Water Level it has to be assumed that through the damping effect some water could remain in the ground, which leads to a higher pore water pressure than the actual water pressure created by the river level.

Interventions before and after Thames Crossing

Before starting the TBM drive there was an intensive discussion on the frequency, the location, the requirements and the procedure for interventions in the



Above: Figure 4, Additional mitigation measures at White Hart Bridge

working chamber. Based on experiences from the project CTRL 320 the abrasion of the cutting tools was evaluated as low although the flint embedded in the chalk is highly abrasive.

Due to the high pore water pressure below the River Thames supporting pressures of more than 3 bars were required for a full face support. To avoid interventions under such high pressures, interventions were planned before and after the crossing of the River Thames. At these locations the geotechnical ground model predicted a structured medium density chalk with a small amount of thin fissures. This good chalk quality allows an optimisation of the interventions. A procedure of tunnel face inspection and monitoring has been developed to allow a reduction of the required air pressure in the working chamber stepwise to 1 bar.

In particular the water inflow has been monitored continuously.

In addition to the interventions required for the TBM drive additional three interventions were made to investigate the chalk characteristic at the locations of the planned cross passages.

SOIL TREATMENT

Separation for the slurry shield

Due to the use of a slurry shield TBM a plant is necessary to filtrate the spoil out of the slurry to recycle it. This task is handled by the slurry treatment plant (STP). To manage the excavated material by a maximum tunnelling advance up to 80mm/min a slurry flow rate of 1600m³/h needs to be treated. This material consists of Terrace gravels, Thanet sands and Chalk with a various amount of flint stones (5 to 25 per cent).

In a first separation step, a scalping unit as a rotating drum with an integrated screen cuts off all the material with a size bigger than 8mm. This material drops straight on a belt conveyor and is transported to the dump. All the slurry and the grains, which passed the openings in the screen, are split in three parallel lines including a desanding and desilting section. In each line two big cyclones with a separating cut of 70µm and 12 small cyclones with a separating cut of 40µm are installed. After passing the desanding and desilting section the slurry will be reused in the slurry circuit.

Chalk separation

Based on experience with a Mixshield TM in chalk the support fluid was replaced with water to achieve stability. The chalk dissolves very quickly after excavation and mixes with the water in the working chamber and the slurry pipes. The particles of the excavated chalk spoil, which are up to a 100 per cent smaller than 40µm, require a special handling.

In former projects the dissolved chalk was handled with centrifuges and afterwards the water content was reduced by

Based on experience with a Mixshield TBM in chalk, the support fluid was replaced with water to achieve stability

CONNECTING YOU TO WORLD-CLASS ELECTRICAL TUNNELLING SOLUTIONS

Ampcontrol is setting benchmarks in tunnelling technology that helps you protect your assets and keep projects on schedule.

Visit us on **Stand B8 at BTS 2014** to view a demonstration of our market leading technology that includes:

- Integrated communications, tagging and tracking
- Environmental monitoring and control
- Emergency evacuation systems
- Power distribution
- Lighting
- Equipment protection

ampcontrolgroup.com/tunnelling **AMPCONTROL®**

TUNNEL SEGMENT GASKETS FROM VIP-POLYMERS

See us at the BTS 2014 Exhibition in September on stand number B56

<https://twitter.com/VIPPolymersLtd>
<https://www.linkedin.com/company/vip-polymers-limited>

For further information please contact us:
 T: +44 (0)1480 411333 F: +44 (0)1480 413991
 E: sales@vip-polymers.com W: www.vip-polymers.com

DATWYLER

HIGH QUALITY GASKETS

International Experience – Proven Longevity

gaskets for precast segmental lining

- monoepdm
- coexslide
- coexswell
- composite gaskets
- anchored gaskets, mono and combined

for road, railway, metro, cable, sewage and water tunnels

www.datwyler.com

Sealing Solutions

www.normet.com

normet
FOR TOUGH JOBS

**FOR TOUGH JOBS
UNDERGROUND**

met
TUGH JOBS

spraymec

CHEMICALS

EQUIPMENT

D-BOLT

SUPPORT

Questions from the floor

Roger Bridge, BTS chair: Thank you for the presentation. It's interesting to see some of the challenges that you have faced. It is a credit to you; it's a superb job. I think now we will take this opportunity to see if anyone has any questions they would like to ask.

Andy Sindle, Crossrail: Could you tell me a bit more about the grouting for the cross passages when you were doing the SCL work in chalk? I would imagine that would have had to be pretty dry for you to be able to do it. You said you treated the ground first, but could you tell us a little bit more about that please?

Answer: At cross passage 19 we did some treatment from the surface in some Thanet Sands on the top because the overburden was only 2m of chalk above cross passage one. For jet grouting in the chalk you have to use microfine cement. This is quite important because the openings are quite small. Cross passages 18, 17 and 16 we did ground treatment from within the bored tunnels. Ascending and descending stage techniques. Open the hole with a picker and microfine cement. And a pattern of 1.5m between the drillings. Performance criteria were agreed with Crossrail.

Colin Mackenzie, retired: First of all, congratulations on a first class presentation. It's one of the best I have seen in a long time. In the portal areas you had temporary works in which you had two levels of struts and these were clearly heavy struts, and the lower ones were hydraulic, and as you were inducing hydraulic loads you would know exactly what loads you were putting in.

Did you find that the loads, how closely the loads corresponded with your design loads because in London there have been cases where the design loads didn't appear... Notably on the Limehouse Link where a major level of struts was eliminated and a lot of money was saved. Did you find that the loads matched the design loads?

Answer: The loads were about 20 per cent of what we anticipated so they were a little bit over-designed. But one reason was by Plumstead portal next to the railway of course we wanted to be on the conservative side but there was a requirement that if one of the props were accidentally removed, the structure would still take all of the loads. And so that is the reason for the very heavy railers and props. But you are right, it can be optimised.

Mackenzie: Noting the proximity of the railway, I'm not surprised that you were forced into a conservative approach. Thank you.

Steve Price, Mapei: I apologise if it's a simple question but I would like to know a bit more about the synthetic membrane and how that seems to waterproof the tunnel, that we saw in one of the slides.

Answer: It is a 1.5mm thick membrane, the placing and testing, and welding is quite important. These are the main requirements and ensure that it is watertight to get the 120-year design life. You need a high quality, and a high standard of inspection.

Chair: Thank you very much for the presentation.

adding a high amount of cement.

In this project an alternative method was used to suit the agreed spoil management and disposal: aim was that the moisture content of produced spoil from the treatment plant shall not exceed 35 per cent. The last separation step was the treatment of the waste mud by carrying out a filtration process with the filter presses. Before the slurry was pumped into the chambers of the filter presses, a defined amount of lime milk was added.

The settings for lime milk concentration and lime dosage were calculated utilizing the values of outflow of waste mud tank measured by a flow- and densimeter. The purpose of lime milk for the filtration process was to accelerate the process

Below: White Hart Road Bridge



itself and also to reduce the stickiness of the filter cake surface to improve the discharge of the filter cakes.

The filtration process includes the steps of closing, feeding, inflating (only membrane filter presses), core blast, opening and demoulding. There are six filter presses, where each allows a treatment of 14.5t/h of dry mud. Four of them were normal chamber filter presses with a maximum closing pressure up to 250 bar, supplied by two hydraulic jacks. Another two were membrane chamber filter presses, which were conducting an additional squeezing/inflating process after the normal feeding process. Due to this additional process, the closing pressure was with 400 bar much higher than with the normal chamber filter presses. The excess mud treatment started with the closing of the 100 chambers of a filter press and was followed by the mud feeding. Thereby a volume of approximately 7,300 litres of limed mud out of the storage silo was pumped into the chambers. The solid particles in the slurry were collecting itself on the surface of the filter cloth and creating a, so called, filter cake. At the same time the water flowed through the cake and the cloth into the plates, where it was led via small channels to

BUSINESS OPINIONS

The Business Insight Community

Set the business agenda by contributing your insight to the community. The Business Opinions Insight Community provides professionals like you with the opportunity to keep up to date with the latest issues and trends being discussed in your industry.

Your views are valued by Business Opinions, which is why we reward you every time you participate. Your contribution is vital.

To join, visit businessopinions.co.uk



a drain into a tank. In consequence of the increasing thickness of filter cake, the pressure in the filter presses went up to 7 bar. At this pressure set-point the feeding pumps were regulated to maintain the pressure at this level for a certain time until the filtration process was finished. Before the core blast sequence started, the inflating mode was carried out by the two membrane filter presses. During this mode, the volume of the chamber was reduced by inflating membranes in the plates utilising 14 bar water pressure.

Due to this compression, residual water contained in the cake was removed. The pressure was held over a certain time until the process was ended by a required criterion.

After finishing this mode the liquid core in the presses needed to be removed. This was necessary to prevent the liquid mud falling down on the dry filter cakes. Therefore compressed air was passed through the centre of the filter press to discharge the material into a small tank, where it is pumped back to the limed mud silo. Before the hydraulic pressure was released, to allow an opening of the plates, the membranes got drained.

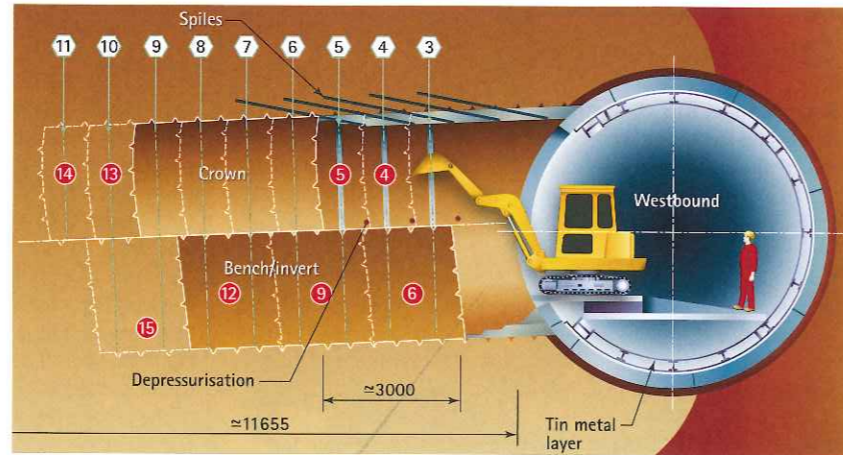
Then in a defined order compressed air was pushed in hydraulic jacks on both sides between the plates to provide enough space for dropping the filtrate cakes.

The discharge of the cakes was done by gravity and supported by shaking of the plates. The cakes falling down in a provided box for collection with a wheel loader were mixed up with material from the belt conveyor and loaded on a lorry.

CROSS PASSAGES

For optimisation the excavation and support concept for the cross passages was changed from SGI Support Elements to Sprayed Concrete Lining. To reduce the permeability of the Chalk and to reduce the water inflow to a manageable level fissure grouting in the area of the future cross passages was carried out within the Chalk. The fissure grouting was executed for two of the four cross passages from the finalized tunnel and for the remaining two cross passages from the ground surface.

Due to the high asymmetric loading on the segmental lining underneath the River Thames (embedding of segments, water pressure and ground treatment) and the low ratio of the diameter of the TBM Tunnel versus the diameter of the cross passage, it was necessary to install a temporary steel support



Above: Figure 5, Construction procedure for cross passages

structure at each cross passage opening location prior to the commencement of the cross passage excavation. The support structure remained in-situ until the cross passage works were completed.

In preparation of the excavation the success of the grouting was proofed with probe drilling and the segments were removed. After excavation and the completion of the sprayed concrete primary lining a waterproof membrane and a cast in situ secondary lining were installed.

For the opening of the segmental lining within the tunnels the alternative use concrete segments with a shear bicone (combined steel and polyamide dowels) in the circumferential joints in lieu of the original designed steel opening sets in the area of the opening was proposed.

To allow the alternative design to work effectively, a higher design concrete strength and combined reinforced segments (steel as well as steel fibre reinforcement) have been developed for five fixed rings in the area of the opening which also integrate a "soft keystone" to simplify the opening and removal works.

References

CIRIA 574: Engineering in Chalk
 Crossrail (May 2007): *Geotechnical Sectional Interpretative, Report 4: Isle of Dogs to Plumstead*, Volume 1: Text. Report No. 1D0101-G0G00-00520, Rev. B
 www.crossrail.co.uk
 Rengshausen, R., Tauriainen, R. and Rädle, A. [2013]. "Crossrail, C310 Thames Tunnel, TBM and Spoil Treatment Selection Process, TBM-S with Slurry face support (Slurry TBM) versus TBM-S with Earth Pressure Balanced face support (EPB TBM)", Geomechanik, Vol. 01/2014
 Tauriainen, R., Ingram, A. and Rädle, A. [2013]. "Cooperative contract basis for fair and proactive solutions of technical challenges in urban tunnelling with low overburden – Practical examples for lining design and opening of the cross passages", Tagungsband STUVA 2013
 CIRIA 574: Engineering in Chalk
 Crossrail (May 2007): *Geotechnical Sectional Interpretative, Report 4: Isle of Dogs to Plumstead*, Volume 1: Text. Report No. 1D0101-G0G00-00520, Rev. B
 www.crossrail.co.uk
 Rengshausen, R., Tauriainen, R. and Rädle, A. [2013]. "Crossrail, C310 Thames Tunnel, TBM and Spoil Treatment Selection Process, TBM-S with Slurry face support (Slurry TBM) versus TBM-S with Earth Pressure Balanced face support (EPB TBM)", Geomechanik, Vol. 01/2014
 Tauriainen, R., Ingram, A. and Rädle, A. [2013]. "Cooperative contract basis for fair and proactive solutions of technical challenges in urban tunnelling with low overburden – Practical examples for lining design and opening of the cross passages", Tagungsband STUVA 2013



We do it better and cost-effectively.



Rowa stands for high competence and long years of experience in tunnelling construction. Our trademark are intelligent and comprehensive solutions from heading to waste disposal sites. We guarantee above-average operational safety and high economic efficiency.

We do it better – the proof is our global clientele's confidence in us.

Rowa Tunnelling Logistics AG, Leuholz 15, CH-8855 Wangen SZ
 Phone +41 (0)55 450 20 30, Fax +41 (0)55 450 20 35
 rowa@rowa-ag.ch, www.rowa-ag.ch



When true effectiveness is spelled s-a-f-e-t-y

With more than 5000 Brokk machines in use worldwide, this remote-controlled little giant has set a new standard for efficient, cost-effective work where power and accessibility is a difficult equation to solve. With its jaw-dropping reach, flexibility and hitting power and with the operator on a safe distance from the action, it maximizes effectiveness and minimizes injuries. Perfect for profitable tunneling projects.

Original Demolition Power™



Tunnels

AND TUNNELLING

The leading tunnelling magazine for 42 years!

SUBSCRIBE TODAY to receive
twelve print + digital issues for the
SPECIAL PRICE of £114.29

To Subscribe:

Make sure you receive your monthly copy of Tunnels & Tunnelling International. Each subscription contains free digital issues & weekly e-newsletter.

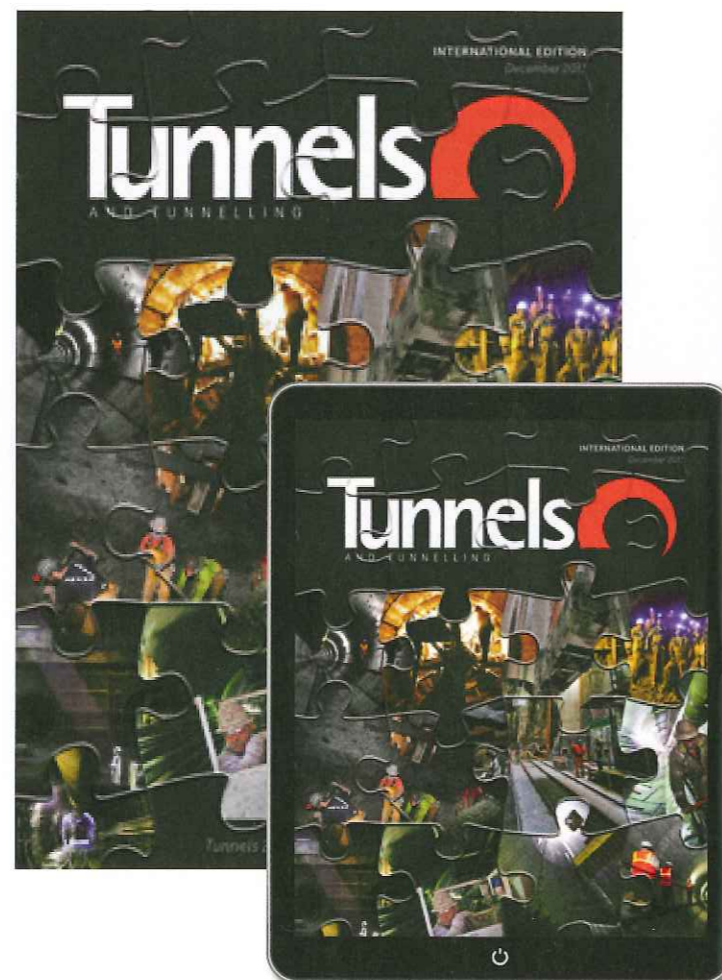
Call: +44 (0)845 073 9607

Email: cs@progressivemediagroup.com

Fax: +44 (0)207 458 4032

Visit: www.tunnelonline.info

Quoting TUN114



International prices, gift subscriptions & back issues available online

CROSSRAIL WESTERN TUNNELS: TBM BREAKTHROUGH AT BOND STREET STATION

The construction of the Crossrail Western Tunnels saw two tunnel boring machines (TBMs) build 13.7km of tunnel below the streets of central London. During this construction there were a number of interfaces, requiring the machines to transit through new, partially built stations. At one of these stations, new Bond Street, the passage of the eastbound machine was problematic; two high strength concrete diaphragm walls had the potential to halt progress 20m below the surface. With the interface imposing a serious risk of delay to the contract, the project team needed to provide a solution permitting the safe passage of the machine and quickly. This paper describes the solution and how the challenge faced was overcome

IMAGINE YOURSELF at London Underground's Canary Wharf Station. After an afternoon of meetings you set off to catch your next business flight out of Heathrow. Your journey starts by boarding the next available westbound Jubilee Line service. Having interchanged, 66 minutes later you arrive at Heathrow Central, ruffled by the heat and overcrowding experienced during your journey. When Crossrail opens in 2018, this journey will be very different. By jumping on the next available, spacious westbound service, you will be propelled across central London and on to Heathrow Central comfortably, efficiently, and without the need to change. Plus, the journey will take no longer than 39 minutes.

When complete, the rail link promises to provide many more improved journeys, a needed boost to the economy and a 10 per cent increase to London's existing rail capacity.

The project, which was conceived in the late eighties, connects Maidenhead and Heathrow in the west to Shenfield and Abbey Wood in the east through the use of 90km of above ground (National Rail) lines and 41km of newly constructed tunnel.

Contract C300 - Western Tunnels comprised the construction of 6.8km of twin - bore 6.2m I.D segmental lined tunnel from Royal Oak portal to Farringdon Station.

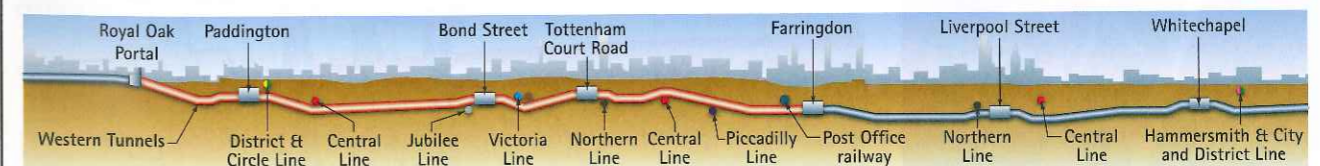
Below: Figure 1, The Western Tunnels pass under the densely populated streets of central London

The contract was awarded in 2010 to a joint venture consisting of BAM Nuttall, Ferrovial Agroman and Kier Construction (BFK). The construction of the Western Tunnels started in 2012 and completion of the second drive was reached in January 2014.

Figure 1, below shows the alignment of the Western Tunnels stretching across central London. The geology encountered along the first 5,000m of the drive was predominantly the upper and lower units of the London Clay. In the east and final 1800m, the alignment declines through the units of

Edward Batty

Edward is the winner of this year's BTS Harding Prize, which is open to any tunnel engineer under the age of 33. He has spent the first two years of his career working for the BAM Ferrovial Kier JV on the Crossrail C300/410 Western Tunnels.



www.tunnelonline.info

September 2014 | Tunnels | 49

the Lambeth Group towards Farringdon Station, where at any time, clay, sand, gravel and laminated layers were simultaneously present at the face.

Such ground conditions led to the design of two soft ground TBMs, which in this instance were manufactured by Herrenknecht. The 7.1m diameter EPB shields had a spoke type cutting wheel with a 55 per cent opening ratio. The cutting wheel tooling comprised a combination of tungsten carbide cutting knives, rippers and cutting discs on the outer radii. In the centre a nosecone was fitted to promote the flow of clay into the excavation chamber.

At different points along the drives the TBMs were required to interface with new, partly constructed, Crossrail stations. These interfaces proved to provide the biggest construction challenges as they required the TBMs to mine sub-surface elements, whether they were piles, diaphragm walls, or zones of foam concrete used to backfill previously excavated sprayed concrete lining (SCL) works.

This paper will focus on the interface of the eastbound machine at the new Bond Street Station and the challenge that it presented.

BOND STREET INTERFACE

Situated in the heart of Mayfair is the new Bond Street Station. Here Crossrail is connected to existing London Underground (LU) Central and Jubilee Lines via a series of ticket halls, passages and station platforms.



Contract	Description
C300/410	C300 – construction of western tunnels, 6.8km twin bored C410 – Bond Street/Tottenham Court Road, station SCL tunnels
C405	Paddington – station construction
C411	Bond Street – station piling for boxes
C412	Bond Street – station main contractor
C421	Tottenham Court Road – station piling for western ticket hall boxes
C422	Tottenham Court Road – station main contractor
C430	Farringdon – station piling boxes
C435	Farringdon – station construction

Source: Author

Advance civils at the station began in August 2011 through contract C411 (table 1), which involved the construction of two station box structures, namely the Eastern and Western Ticket Halls.

As the eastbound TBM advanced through the station, it was required to break into, transit across and break out of both ticket hall boxes.

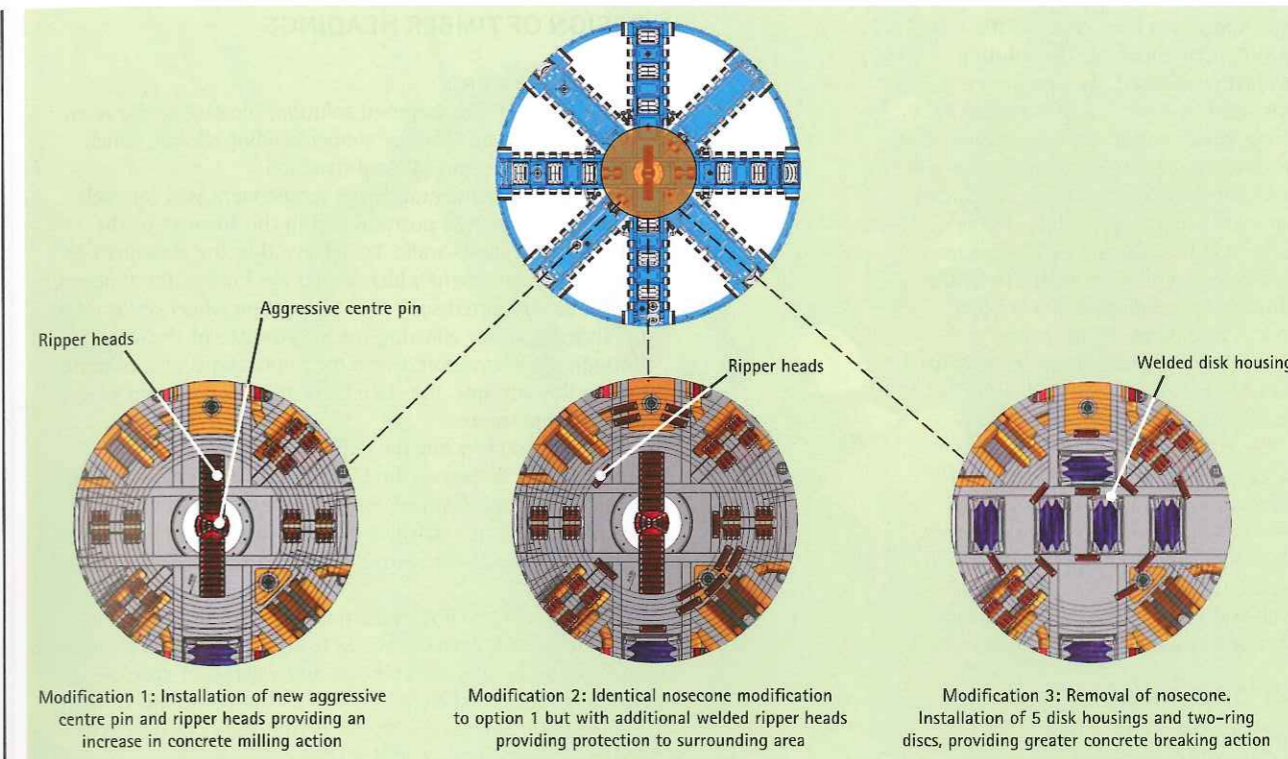
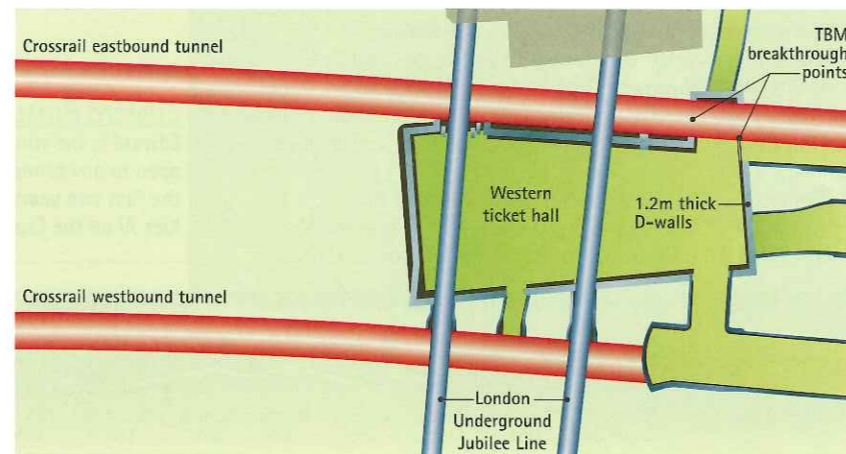
The Western Ticket Hall comprises a 1.2m thick diaphragm wall (D-wall) of top down construction. Here the TBM break in and break out points were 12m (8 rings) apart and at a depth of 20m below the ground surface in the London Clay (Figure 2, below).

In the area surrounding the ticket hall a number of critical assets are present, most notably the north and southbound Jubilee Lines which lay 4m below the invert of the eastbound tunnel extrados. Their close proximity placed them within the zone of influence of the TBM during its transit through the ticket hall. Above ground an abundance of commercial and residential units can be found, some of which were identified as potentially sensitive to the ground borne noise and vibration (GBNV) associated with construction works. One of these receptors, Grays Antiques, was considered high risk due to the fragile and high value nature of its stock.

Initial plans had set out for the free air transit of the TBM across the previously excavated ticket hall, but due to variation in the station excavation programme, the box would now remain largely unexcavated on the arrival of the machine.

At the break in and break out points, the ticket hall D-walls comprised GRP reinforcement cast into structural concrete of an estimated strength of 65N/mm. Given the machine

Below: Figure 2, The new Bond Street Western Ticket Hall will connect Crossrail to the Jubilee and Central lines



had been optimised for soft ground performance, such wall properties gave rise to a problem. The strength and thickness of the walls introduced a significant possibility of wear to the cutting tools and the protruding nose cone during excavation.

The Herrenknecht cutting wheel had the ability to employ two-ring discs (for harder material) on a number of radii, but with the nearest disc track 1.1m away from the centre, even with these tools, the potential for wear to the nosecone remained.

Wear to the nosecone cutting tools during the breakthrough was seen as a significant issue, as repair or replacement of the tools from within the walls would be difficult, time consuming and costly to achieve.

Given the risk of attempting the breakthroughs with 'do nothing' approach the project team set out to find a solution that would provide the quick and safe passage of the machine through the ticket hall, whilst minimising disruption to the surrounding area.

CONSIDERATION OF OPTIONS

During a series of meetings between the parties involved, two initial solutions came to light. The first solution was proposed by TBM manufacturer Herrenknecht and aimed to increase the concrete excavation performance of the central area of the cutting wheel through a number of modifications (Figure 3, above). The second solution took a different approach. By excavating a small area of the northeast corner of the ticket hall, in advance of the main station programme, areas of the D-walls could be broken out from inside.

An assessment of the two solutions was undertaken in which a number of drawbacks were identified. Even with the cutting wheel modifications further time consuming tool

Above: Figure 3, Cutting wheel modification options proposed by Herrenknecht

changes were likely to be required whilst mining through the high strength concrete walls. The proposed ticket hall excavation and breakout works would be carried out using contract C300 resources working from the contract C411 site. Such a set up would give rise to a complex work environment and contractual issues which would be hard to overcome. Furthermore, initial estimates suggested the works could delay the TBM by 9 to 11 weeks.

In a set of follow up meetings the team discussed a less conventional approach to the problem, which involved the construction of a staged heading in front of each D-wall. These headings would be driven from the TBM excavation chamber, by hand, using traditional timbering techniques. On completion of each heading, sections of the D-wall which lie directly in front of the nose cone would be demolished from within the timber / steel lined cavern.

The proposal had a number of advantages over the previous solutions. Gaining access to the walls in such a way eliminated the complexities of C411 site working, whilst given the confined nature of the breakout works, the impact of ground borne noise and vibration would be significantly reduced. With an estimated programme of two weeks per wall, implementation of the solution would also be significantly shorter than the alternatives.

Although historically, surface settlements related to traditional

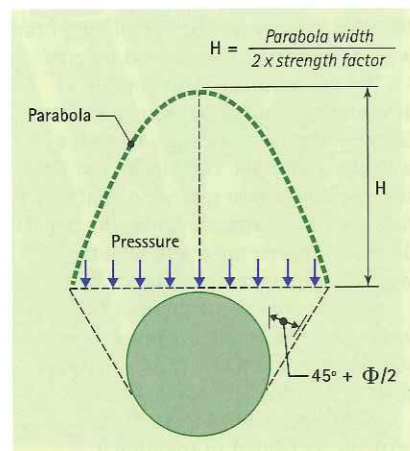
Wear to the nosecone cutting tools during the breakthrough was a significant issue

timbering works have caused little issue, the potential impact of the solution was first considered. By assuming a worst-case volume loss of three per cent during construction, the team assessed the potential settlement impact to assets above the excavations. It was concluded that even with a volume loss of this magnitude there would be little or no impact on the piled foundations of the surrounding buildings. Furthermore, services in the area identified as susceptible to damage from settlements had been previously replaced with flexible, plastic alternatives.

The construction of the headings was seen as a challenge, but with an abundance of handwork-experienced miners already employed on the project, the team was confident the work could be executed safely and accurately. This combined with the advantages already identified saw the third solution selected

THE CHOSEN SOLUTION

- Advance the TBM towards the ticket hall; park a short distance from the first wall.
- Gain access to the excavation chamber using the air locks.
- Construct the staged timber heading in front of the cutting wheel, exposing the area of D-wall with which the nosecone will intersect.
- Breakout a 2.1m diameter circular section of the wall positioned directly in front of the nosecone.
- Change the existing clay ripper tools for two-ring discs to provide additional breaking power to other areas of the cutting wheel.
- Advance the TBM through the heading and break through the wall, building rings behind the shield normally
- Back-grout the rings built within the heading, filling any remaining void left from the heading excavation.
- Repeat process for the second D-wall.



DESIGN OF TIMBER HEADINGS

Key requirements

Having selected the preferred solution, the task of the team was to develop an effective timber heading design, which permitted simple and safe construction.

The first fundamental design requirement was for each heading to remain in position during the advance of the TBM through the D-walls. To achieve this, the crownbars (a horizontal component which carries the load of the timbers), had to be supported such that the cutting wheel could rotate, unhindered, whilst allowing for the advance of the shield through the excavation. Given the implications of a collapse during this advance, the stability of the structure was of utmost importance.

In order to carry out the required breakout works, the headings had to expose the D-walls to a level below the axis of the TBM cutting wheel. Furthermore, the depth of each heading had to be sufficient to accommodate the required tooling for the job and provide ample space to carry out the works safely.

Given that the TBM excavation chamber air locks were going to provide the sole access to the work area, the materials used had to be of a suitable size and weight for ease of handling. Structural elements such as the crownbars needed to be designed in such a way to permit their erection in a confined space in front of the TBM.

The solution resulted in the first heading remaining permanently in the ground outside the ticket hall, therefore the materials used had to resist rotting. With the second heading this feature was less important; future excavation of the ticket hall would unearth the structure.

Due to the limited ventilation possibilities to the work area, the construction method had to limit, if not eliminate the need for welding. Nevertheless, the materials used for the works required a good level of fire resistance.

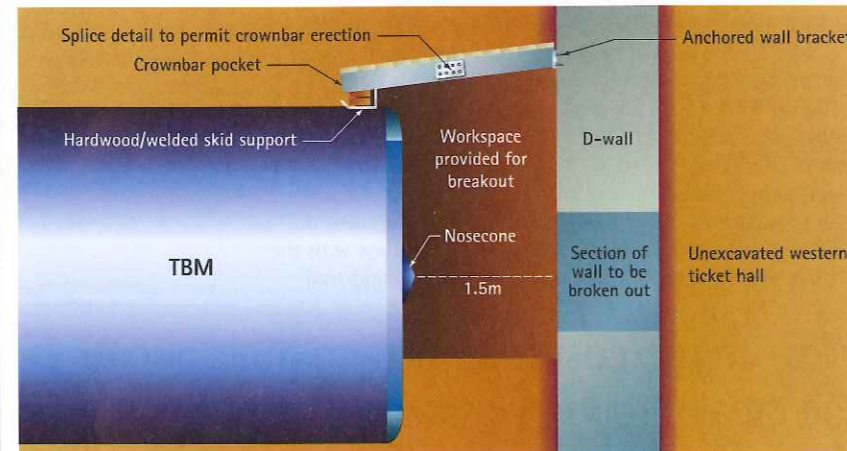
Design

When excavating a tunnel in London Clay, theoretically the following things happen. Firstly the initial excavation results in a loosened zone around the subsequent void accompanied by an arching of the ground prior to the installation of excavation support.

Secondly, the load experienced on those supports gradually increases due to the long-term plastic behaviour of the soil, squeezing the excavation. Taking this, and given that the design life of each heading would be no longer than two weeks, a temporary approach could be taken to the design loading in which only a percentage of the soil column above

Below, left: Figure 4, Protodyakonov's loading curve

Below, right: Figure 5, Cross-section of the final heading design



the excavation was mobilised.

There are a number of methods that permit the calculation of the short term ground loading just described, but here designer Alan Auld Engineering, selected Protodyakonov's de-coupled arch theory. The theory assumes a loosened zone around an opening independent of depth (Figure 4, opposite). This loosened zone of parabolic nature is a function of parabola width and soil strength factor (London Clay = 1).

In this instance the time dependant loading set out in LU guidance (LU G055 - Civil Engineering - Deep Tubes and Shafts) was not considered due to the small size of the opening, the frictional support provided by the D-wall, and the containment of the TBM cutterhead. LU guidance does not specifically take into account tunnel size and is based on empirical data observed from LU tunnels of a range of sizes. Generally in smaller openings a greater degree of soil arching can take place over an excavation resulting in a reduction of stress on the tunnel crown.

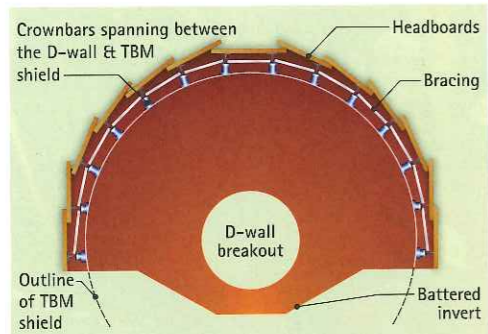
In addition to the loading provided through Protodyakonov's theory, the side legs, which would provide a temporary vertical support during each heading stage, were checked for adequacy against wedge failure. Such failures, in the London Clay, are traditionally known as 'greasybacks' and arise from naturally occurring discontinuities in the soil.

The heading elements were designed to ultimate limit

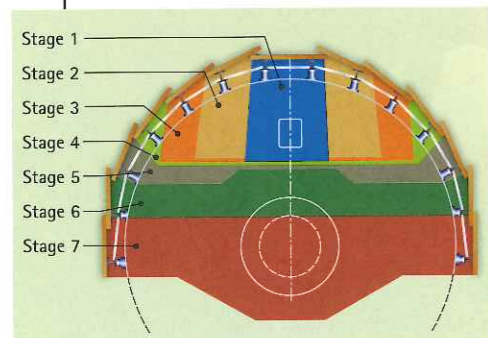
state using a combination of BS EN 1990:2002 (Basis of structural design), BS EN 1995 1 - 1 - 2004 (Design of timber structures) and BS EN 1993-1-1:2005 (Design of steel structures). TEDDS, a structural design software, was employed to check the adequacy of steel members.

A cross section through the resultant design can be seen in Figure 5. The final design included a traditional timber structure using 200mm by 100mm Grade C24 tanalised timber throughout and 14no UC 203 x 203 x 46 crownbars spanning from the shield to the D-wall at 1m centres. The crownbars were supported at the D-wall with anchored brackets, and on the TBM shield 1.2m outbye of the cutting wheel edge with hardwood blocks fixed by a welded skid support. The skids role was to permit the sliding of the supports over the shield on the advance of the TBM. The length of the skid was sized in a way to eliminate the possibility of the support jamming or becoming stuck in the shield articulation joints. The end of each crownbar was pocketed into the clay, this effectively restricted vertical and lateral movement during the advance of the TBM. In front of the cutting wheel each heading

With an abundance of handwork experienced miners... the team was confident



Left: Figure 6, Cross-section through the heading looking towards the D-wall



Left, below: Figure 7, Diagram illustrating the seven stages of the heading works

provided a minimum 1.5m working space between the nosecone and D-wall, ample space for the stitch drill / hydraulic bursting breakout method that had been selected for the demolition.

The crownbars were inclined at six degrees from the horizontal, this resulted in a much discussed 450mm clearance between the outer radius of the cutting wheel and the underside of the wall anchored bracket. The 450mm was a trade-off between the minimum safe distance to allow the cutting wheel to rotate and the time required to carry out each excavation.

The crownbars included a central splice detail that permitted the handling of smaller elements through the air locks. Bracing between crownbars provided rigidity, an essential aspect during the movement of the shield.

The heading invert was battered in a channel like fashion, this promoted the drainage of water arising from the coring works into the excavation chamber. Here submersible pumps would transfer any water to the TBM waste water system and out of the tunnel (Figure 6).

Safeguarding the china

Given the key receptors surrounding the ticket hall, the potential GBNV impacts arising from the works were first assessed in order to justify a need for monitoring.

Experience gained through on-going BFK SCL works in the area (C410 Bond Street Station platforms) led to a belief that there would be no ground borne noise disruption at two key residential receptors, The Cavendish Building and

Hanover Flats. However, Gray's Antiques, a two floor building, which houses 200 antiques dealers selling items ranging from irreplaceable ancient artefacts to modern day collectables, raised concern.

Assessment of the building's interior led to the setting of a vibration threshold level of 3mm/s for the duration of the works.

Trained acousticians equipped with a series of ultra-quiet, ultra-low frequency accelerometers were tasked with monitoring vibration levels, halting the works in the event of a breach.

CONSTRUCTION

Approaching the ticket hall

Construction began with the advance of the TBM towards the ticket hall. To validate the position of the first wall, the face was probed from within the excavation chamber. Validating



Save money – register online

bauma China 2014

November 25 – 28, Shanghai

SHANGHAI
NEW INTERNATIONAL
EXPO CENTRE

BUILDING
SUSTAINABLE SUCCESS

7TH INTERNATIONAL TRADE FAIR FOR
CONSTRUCTION MACHINERY,
BUILDING MATERIAL MACHINES,
CONSTRUCTION VEHICLES
AND EQUIPMENT

www.bauma-china.com

Going further in 2014

A complete subsurface construction source for the utilities industry



the wall position was an essential aspect of the approach, as parking too close would reduce the workspace in front of the cutting wheel, hindering the construction of the timber heading and the breakout works to follow.

Transforming the excavation chamber

Having reached the required position the excavation chamber was depressurised and the level of spoil within the chamber reduced. The remaining spoil provided an element of earth balance below axis, whilst above axis the face was boxed up with timber between the cutting wheel spokes. These timbers would keep the face under control prior to the development of the heading.

Following this, the excavation chamber was transformed to accommodate the upcoming handwork. Secondary ventilation, lighting and power made its way to the excavation chamber through the bulkheads redundant smaller openings. A series of micro conveyors passing through the material lock and discharging onto the TBM conveyor system would aid the removal of spoil from the work area. The man lock at the top of the excavation chamber was kept free for the passage of miners, primary ventilation, tools and materials. The first TBM gantry also had a new purpose, here a backup team of miners worked to prepare the timber, grout and steel required for the works.

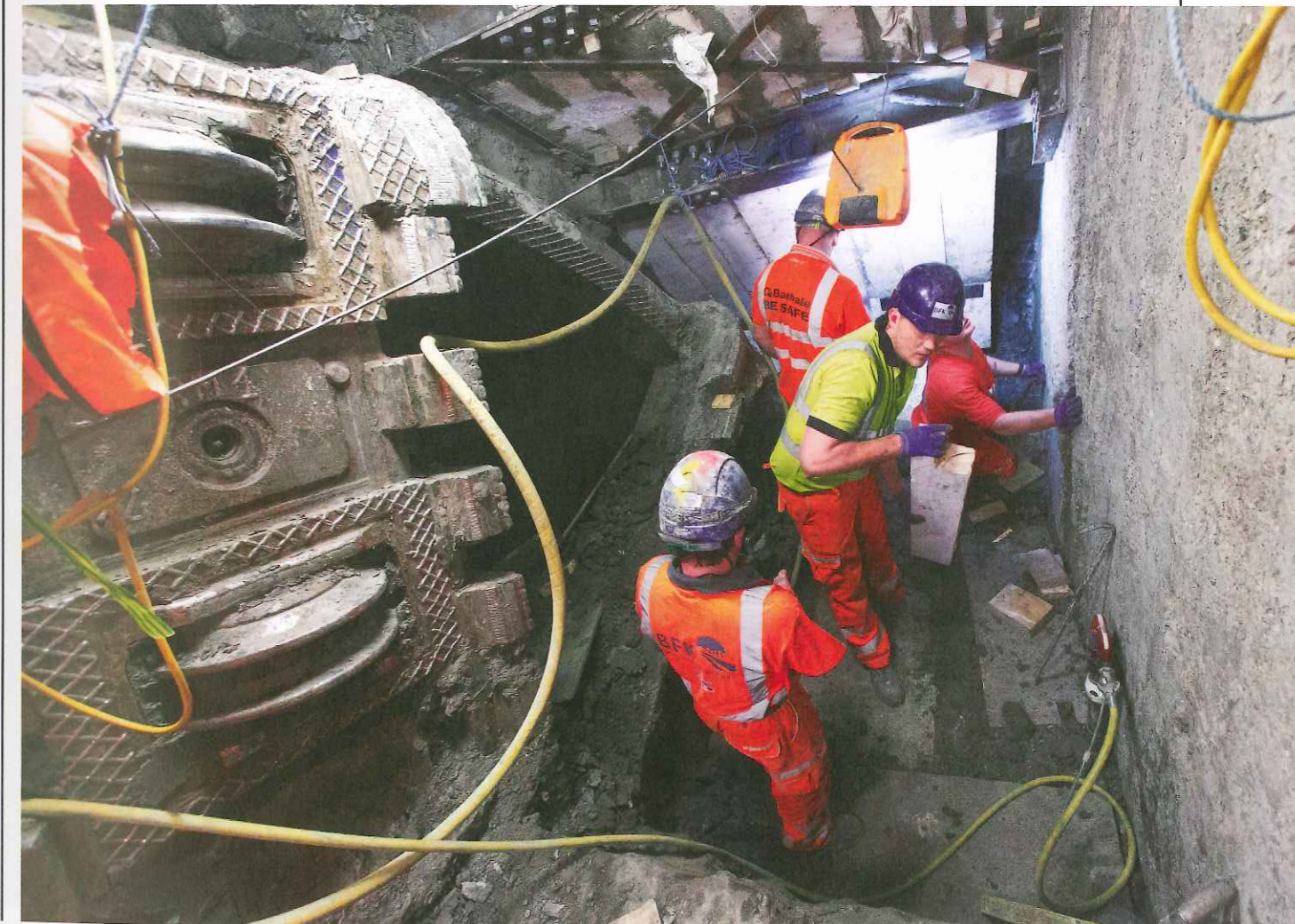
Traditional timbering

Equipped with FL22 clay spades the miners began the

timbering works by driving an initial box heading towards the D-wall through the window of two cutting wheel spokes orientated to the vertical. Once complete the unearthing of a smooth D-wall finish was a welcome sight, this would aid the installation of the crownbar wall supports.

Advancing back over the shield, the first crownbar pockets were excavated. The excavation of the pockets was particularly difficult due to the required depth and narrowness of the opening. In hindsight the crownbars should have been set slightly higher at the shield to aid the excavation and installation of the welded skid supports. Nevertheless, the installation was still achievable and the level of vertical and lateral restraint provided by the pockets was excellent. Following the completion of the pockets the first crownbars were erected with the aid of a temporary support system.

Over the next six days, the seven stages of the heading works were carried out, in which 90t of London Clay was removed from the excavation (Figure 7, page 54).



Throughout this period the timbering was regularly inspected to ensure proper tightening against the face. Tightening, which is also known as pre-loading, is a fundamental aspect of timbering within London Clay. In short term excavations such as this, failure arising from overburden pressure is a rarity, but is more likely to result from the local wedge failures previously described. Tightening timbers against the clay effectively restrains any potential soil wedge by restricting movement. Here, the tightening of headboards (a horizontal timber which spans between crownbars) was achieved with the use of hard wood wedges and grouting of the void between timber and the clay face on regular intervals. The latter also ensured full transfer of load to the timber-steel support system, whilst sealing the face to prevent drying and deterioration of the soil.

Management of percussive tools

Since the introduction of legislation controlling vibration at work, the management of exposure to hand arm vibration (HAV) has become a major aspect of traditional timbering works due to the nature of the percussive tools used. Exposure limits set out in these regulations are fundamental to this management and in certain circumstances can make such work costly and hard to achieve.

Here central to the management of HAV was the correct selection of gang size and baseline scoring of the men.

The timbering works were carried out around the clock, with three shifts per 24 hour period.

Each shift comprised a gang of 16 miners working 8 hours at the face. Of the 16 miners, 10 were on rotation for the handwork, the remaining six provided backup from the TBM.

Using best practice guidance (BTS - The Management of Hand-Arm Vibration in Tunnelling) estimated trigger intermittency levels for excavation in London Clay were consulted and used as the basis of rotation management. These values were later confirmed through monitoring carried out during the works.

Breakout of the D-wall

On the completion of the first heading the breakout works commenced. The circumference of the breakout section was stitch-cored to provide a relief line to break to (see photo, page 53).

A relief line allows the concrete to be displaced when put under tensile stress, which ultimately leads to its failure. Additional smaller diameter cores were

References

- Szechy, K (1966), *The Art of Tunnelling*, Budapest: Akadémiai Kiadó,
 Mackenzie, C (2011), *Traditional Timbering in Soft Ground Tunnelling*, London: Unpublished Draft Copy
 The British Tunnelling Society (2006) *The Management of Hand Arm Vibration in Tunnelling Guide to Good Practice*, [Online], Available <http://www.hse.gov.uk/vibration/hav/campaign/construction/tunnelling.htm> [March 2012]
 London Underground (2012), Guidance Document G055 Civil Engineering Deep Tube Tunnels & Shafts

drilled in the centre of the concrete mass to accommodate a low vibration hydraulic wedge, which was used to burst the concrete.

The breakout works went very well, taking just two days to complete.

Breakthrough

Following the breakout, the TBM advanced through the heading and began mining the first wall. During this 1.2m advance through the concrete a penetration rate of 5mm/rotation was maintained to keep torque and heat to a minimum. The breakthrough was a success taking just three hours to complete.

Following the success of the first D-wall the TBM advanced to opposite side of the ticket hall where the process was repeated.

From start to finish the ticket hall transit took three weeks to complete, this was a significant gain on the initial programme. During the works the installation of a tunnel conveyor booster motor was re-programmed to minimise lost time.

The acousticians positioned at Gray's Antiques obtained satisfactory results. The work produced vibration peaks well below pre-determined trigger levels and more importantly no stock at Gray's Antiques was damaged.

The Jubilee Lines experienced 1mm heave as a result of the TBM transit and above ground recorded surface settlements were negligible.

Following the breakthrough of the second wall the TBM was stopped again for a cutting wheel inspection. There was no wear to the clay knives and hard facing. More crucially, no damage to the nose cone and the surrounding area was sustained.

CONCLUSION

The new Bond Street interface had the potential to inflict serious cost and delays to the Western Tunnels project. Through a thorough assessment of the options available the team were able to identify a solution that eliminated the risk of damage to the TBM tooling, whilst minimising disruption to the adjacent station works and surrounding area.

The solution was successful in achieving its objectives and the eastbound TBM went on to finish the remainder of its drive in a successful manner. Interfacing a TBM with a station may seem simple on paper, but in reality it can produce some of the more complex challenges faced on modern day metro projects. The obstacles the new Bond Street Station presented reinforces the need for good detail at these interfaces and an understanding of requirements between all parties involved.

The way in which the project team overcame this challenge reinforces the fact that techniques used to construct the first tube lines 150 years ago are still an invaluable asset to the industry today

The author would like to thank all the parties involved in the development of the solution and the success of the works including Crossrail, BAM/Ferrovial/Kier joint venture, Herrenknecht and the designers, Alan Auld Engineering. Special thanks go to the Alan Auld Engineering design team for their efforts in getting a design out in such a short period of time. And also Crossrail for their approval for submission.

ITAWTC 2015

41st General Assembly and Congress of
International Tunnelling Association ITA-AITES



SEE TUNNEL

PROMOTING TUNNELLING IN SEE REGION

LACROMA VALAMAR CONGRESS CENTER MAY 22-28, 2015
DUBROVNIK, CROATIA



ITA CROATIA
Croatian Association for
Tunnels and Underground
Structures



ITA-AITES
International Tunnelling
and Underground Space
Association

To advertise here call Tom Willard on +44 (0) 203 096 2608 or email twillard@tunnelsonline.info



This is not the full list of British Tunnelling Society Corporate Members | To see a full list of all members visit: www.britishtunnelling.org.uk

ARUP
 T: +44 (0)20 7636 1531
 E: london@arup.com
 W: www.arup.com

ATKINS

www.atkinglobal.com

Balfour Beatty
 Civil Engineering
 +44 (0)1737 785 000
enquiries@bbcel.co.uk
www.bbcel.co.uk

BASF
 The Chemical Company
www.ugc.basf.com



If you wish to become a British Tunnelling Society Corporate Member please email: bts@britishtunnelling.org.uk

McGINLEY
 SUPPORT SERVICES
 01923 696 600
 07974 789 715
www.mcginley.co.uk

MORGAN SINDALL
 01788 534 500
morgansindall.com

Mott MacDonald
 Mark Leggett
 T: +44 (0)20 8774 2758
mark.leggett@mottmac.com
www.tunnels.mottmac.com

Natural Cement
www.naturalcement.co.uk

Cooper & Turner
 TUNNELLING DIVISION
 Designers, manufacturers and suppliers of connection and embedded accessories for concrete segmentally lined tunnels.
 Tel: +44 (0) 114 256 0057
www.cooperandturner.co.uk

COSTAIN
 Stephen Meadowcroft
 T: +44 (0)162 884 2444
stephen.meadowcroft@costain.com
www.costain.com

DANNY SULLIVAN GROUP
enquiries@dannysullivan.co.uk
 +44 (0)20 8961 1900
www.dannysullivan.co.uk

DONALDSON ASSOCIATES
www.donaldsonassociates.com

otb
 CONSULTING, DESIGN, SUPERVISION
 +44 (0)20 7099 2608
enquiries@otbeng.com
www.otbeng.com

Global consultants | Designers
 Engineers | Programme managers
PARSONS BRINCKERHOFF
www.pbworld.com
services@pbworld.com

Rutherford
 global power
 TEMPORARY ELECTRICAL EQUIPMENT & CABLES FOR TUNNELLING & CONSTRUCTION
 TEL: +44 (0) 1206 596 100
info.uk@rutherfordgp.com
www.rutherfordglobalpower.com

SHAY MURTAGH
 Precast Concrete Tunnel Segment Specialists

www.shaymurtagh.co.uk

Dr. SAUER & PARTNERS
 T: +44 208 339 7090
london@dr-sauer.com
www.dr-sauer.com

Elkem
 A Bluestar Company
 contact John Finch:
 01142 700334
 07765 232 284
John.finch@elkem.no
www.elkem.com

Gall Zeidler CONSULTANTS
 GEOTECHNICS | TUNNEL DESIGN | ENGINEERING

www.gzconsultants.com

GRACE de neef
 Leader in injection and waterproofing products
www.deneef.com

SHOTCRETE
 SPECIALIST SPRAYED CONCRETE SERVICES
 Plant & Equipment Sales + Hire
 Contract Works - Labour Supply
www.shotcrete.co.uk

stirling lloyd
 THE TECHNOLOGY OF PROTECTION
 SEAMLESS WATERPROOFING TO CREATE WATERTIGHT TUNNELS
 01565 633111
marketing@stirlinglloyd.com
www.tunnelwaterproofing.com

TIMER SOLUTIONS
 Waterproofing system.
 From secured rock to finished tunnel in 8 cm!
 +47 9798 2850 - nesheim@tiso.no
www.tiso.no

URS
 Multidisciplinary engineering consultancy
 +44 (0)121 212 3035
uktunnelling@urs.com
ursglobal.com

Ha-Be
 Making good concrete better
 CONCRETE ADMIXTURES for underground constructions
www.ha-be.com

HALFEN
 YOUR BEST CONNECTIONS
 01582 470300
WWW.HALFEN.CO.UK

HERRENKNECHT
 Tunnelling Systems
www.herrenknecht.com

Hunter Personnel
 Recruiting For Your Industry
 Specialists in Tunnelling and Infrastructure Recruitment
www.hunterpersonnel.com

VINCI CONSTRUCTION | GRANDS PROJETS
 Tunnelling works:
 world class innovative solutions
www.vinci-construction-projects.com/british-isles

VIP Polymers Ltd
 TUNNEL SEGMENT GASKETS
 T: +44 (0)1480 411333
sales@vip-polymers.com
www.vip-polymers.com

VVB Engineering Services Ltd
 Mechanical & Electrical Engineering
 tel +44 (0)1268 711845 | fax +44 (0)1268 711846
www.vvb-eng.com

PROJECT LOGISTICS
W&W | **ALS**
 WALLENUS WILHELMSEN LOGISTICS | ABNORMAL LOAD SERVICES
 WWL ALS will be exhibiting at the British Tunnelling Society, London 23-24 Sept 14. We look forward to welcoming you at our stand F10.
 Tel: +44 (0) 1482 796214
info.tunnelling@als-europe.com
www.wwlals.com

IRIS
 Intelligent Radio Solutions
 'Designing Solutions through Networks'
info@intelligentradiosolutions.com
 +44 (0)1223 906052
www.intelligentradiosolutions.com

itmsoil
 t: +44 (0) 1825 765044 e: info@itmsoil.com
 f: +44 (0) 1825 744398 w: www.itmsoil.com

J G L
 Joseph Gallagher Ltd
 Tel: +44 (0)1375 672070
 Fax: +44 (0)1375 672073
 Email: headoffice@josephgallagher.co.uk

Lba
 LONDON BRIDGE ASSOCIATES LTD.
www.lbassoc.co.uk
 Delivering value across the construction cycle.

This is not the full list of British Tunnelling Society Corporate Members. To see a full list of all members visit: www.britishtunnelling.org.uk
 If you wish to become a British Tunnelling Society Corporate Member please email: bts@britishtunnelling.org.uk

To advertise here call Tom Willard on +44 (0) 203 096 2608 or email twillard@tunnelsonline.info

BORING EQUIPMENT



TERRATEC
www.terratec.co

CHEMICALS



BASF
The Chemical Company
www.ugc.basf.com

CUTTER TOOLS



PALMIERI TUNNELLING - DRILLING
CUSTOM-MADE CUTTERHEADS FOR TBMs MICROTUNNELLING AND VERTICAL OR DIRECTIONAL DRILLING MACHINES.
BACK UP AND MUCK HAULAGE SYSTEMS.
ROLLING STOCK AND SPECIAL TUNNELLING RELATED EQUIPMENT
T: +39 0534 32511 F: +39 0534 32501
E: info@palmierigroup.com W: www.palmierigroup.com
Agents wanted in selected countries. Please apply to: a.tasselli@palmierigroup.com

CUTTER TOOLS



T.B.M. CUTTERS Ltd.
DESIGN AND MANUFACTURE OF TBM CUTTING TOOLS AND WEARPARTS
CUTTER HEADS MANUFACTURED & MODIFIED
TEL: +44 (0) 1430 427954 FAX: +44 (0) 1430 427955
EMAIL: office@tbmcutters.com www.tbmcutters.com

DIRECTIONAL DRILLING



devico
DIRECTIONAL CORE DRILLING & BOREHOLE SURVEYING INSTRUMENTS
Contact us devico@devico.no www.devico.com

EQUIPMENT



EAVES
Tunnel Linings
Bespoke Heavy Engineering Solutions
100 tonne single lift capacity
0161 223 0400
www.eavesmachining.com

Sp SPECIALIST PLANT
TUNNELLING EQUIPMENT
HIRE AND SUPPLY
Tunnel Ventilation Systems
UK Agents for **SVEBRA** LIGHTWEIGHT PIPING
Tel: +44 (0) 1234 781 882
Email: info@specialistplant.co.uk
www.specialistplant.co.uk

The one-stop source for the tunnelling industry.
It's only a mouse click from here!
tunneltrade.com
Your tunnel internet portal

A.S.T. Bochum
Special fittings, hoses and tunnelling equipment
www.astbochum.de
Erection plant
Machine requirements
Microtunnelling
Drill & Blast tunnelling
Air pressure supply
Concrete formwork engineering
Special civil engineering
Shot concrete engineering
TBM tunnelling
Freezing engineering
Wearing protection
Pipe-Systems
Tel: +49 (0)234 / 59963 10 • Fax: +49 (0)234 / 59963 20
www.astbochum.de

DRILL and BLAST



OSSA
OBRAS SUBTERRANEAS
1952 - 2012
Polígono Industrial Alcobendas.
28108 Alcobendas (Madrid)
T. +34 902 678 808 | F. +34 915 618 894
www.ossaint.com

ELEVATORS



ALIMAK HEK
Rack and pinion elevators for inspection, maintenance and emergency escape in road and railway tunnel shafts.
www.alimakhek.com

GROUND CONTROL



DSI
DYWIDAG-SYSTEMS INTERNATIONAL
ALWAG SYSTEMS
GROUND CONTROL SOLUTIONS
UNDERGROUND SYSTEMS INC.
www.dsi-tunneling.com



hw hoelscher dewatering
- dewatering
- groundwater control
- water treatment
www.hw-dewatering.com

MICROTUNNELLING

WHEN THE GOING GETS TOUGH...
...Iseki microtunnelling machines come smiling through!
Microtunnelling equipment - for hire or sale
ISEKI MICROTUNNELLING
Iseki Microtunnelling
Wellingborough UK
+44(0)1234 781166
www.isekimicro.com

ENGINEERING CONSULTANTS



GEOCONTROL
BRASIL | CHILE | ESPAÑA | PERÚ
TUNNEL ENGINEERING
GEOLOGICAL / GEOTECHNICAL ENGINEERING
TUNNEL SAFETY INSTALLATIONS
ROCK MECHANICS APPLIED TO MINING
TECHNICAL ADVICE DURING CONSTRUCTION
SITE SUPERVISION
Cristóbal Bordiú, 19-21, 5º - 28003 Madrid (SP)
T: +34 91 533 17 63 | F: +34 91 554 93 96
geocontrol@geocontrol.es

Your Trustworthy Tunneling Consultant Since 1962
CONSULTING ENGINEERS
SAANIO & RIEKKOLA OY
Laulukuja 4, FI-00420 Helsinki, Finland
tel. +358 9 530 6540, www.sroy.fi

MONITORING EQUIPMENT

Tunnel Atmosphere Monitoring
Carbon Monoxide
Nitric Oxide
Nitrogen Dioxide
Visibility
Air Flow & Direction
Low cost high precision tunnel sensors proven over 20 years
CODEL International Ltd
+44 (0) 1629 814351
sales@codel.co.uk
www.codel.co.uk
World leaders in tunnel atmosphere monitoring

MONITORING EQUIPMENT

EALY TAPE EXTENSOMETER
Cost effective solution for tunnel and structural monitoring
www.tape-extensometer.com
Tel: +44 (0) 1424 729872
or search the internet for your local agent

ENGINEERING CONSULTANTS

TONY RIDLEY HYPERBARIC ASSOCIATES LTD
Consultancy, Expertise and Personnel
Specialist Tunnelling Services
Compressed Air - TBM Intervention - Safety - Rescue - Occupational Health
Tel +44 (0) 1508 538 838 Fax +44 (0) 1508 538 938
Email info@hyperbaric-tunnelling.com
www.hyperbaric-tunnelling.com



Alan Auld ENGINEERING
Tunnel and Shaft Design.
Temporary Works Specialists.
www.alanauld.com
+44(0) 1302 329 911

Tunnels - Caverns
Foundations - Slopes
Consultants in Rock Engineering
GEO-DESIGN
www.geo-design.co.uk

PIPES and COUPLINGS




ALVENIUS
Performance in Piping
New & Used Pipe Systems
Shouldered & Grooved • Galvanized & TP-Coated
P.O. Box 550, SE-631 07 ESKILSTUNA, SWEDEN, Phone: +46 16 16 65 00, www.alvenius.com

PIPES and COUPLINGS



SVEBRA
LIGHTWEIGHT PIPING
Quick Coupling Pipes And Fittings
www.svebra.se

PRECAST CONCRETE



MACRETE
028 7965 0471
www.macrete.com
Specialists in precast tunnel and shaft systems
To advertise in the Business Directory contact Tom Willard on: +44 203 096 2608 or email twillard@tunnelsonline.info

To advertise here call Tom Willard on +44 (0) 203 096 2608 or email twillard@tunnelsonline.info

RAIL and ROLLING STOCK

Maschinen
Stahlbau
LSD
Dresden
Branch of Henschel AG

Jobsite logistics
Shaft installations
Customized back-up systems
High-performance rolling stock
www.msd-dresden.de

World Leading
**Locomotives
& Haulage
Solutions...**

Clayton
Solutions...

...for Mining,
Tunnelling
& Surface
Transport

Clayton Equipment Ltd
www.claytonequipment.co.uk
Tel: +44 (0) 870 112 9191

SURVEYING and MONITORING

**AMBERG
TECHNOLOGIES**

Tunnel Surveying
Tunnel Seismics

www.amberg.ch/at

VMT

www.vmt-gmbh.de

TUNNELLING SUPPLIES

EPDM GASKETS BULLFLEX
PLASTIC SEGMENT FITTINGS SEALING STRIPS
FOAMS & POLYMERS SECONDARY SEALS
HYDROPHYLIC RUBBER TBM LAUNCH SEALS
BOLTS LUBRICANTS
PACKERS ROLLING STOCK
LIFTING EQUIPMENT

**TA Tunnelling
Accessories**

+44 (0) 1424 854112
info@tunnellingaccessories.co.uk
www.tunnellingaccessories.co.uk

TUNNEL DESIGN

Tunnel Design
Technical Assistance
Monitoring
ADECO-RS® approach

ROCKSOIL
S.p.A.

Tel: +39.02.65.54.323
e-mail: rocksoil@tin.it
<http://www.rocksoil.com>

VENTILATION

**SCHAUBURG
TUNNEL-VENTILATION GMBH**

Flexible Ventilation Ducting

www.tunnel-ventilation.de
Phone: +49 208 8827610
Fax: +49 208 8827615

VENTILATION

**NAYLOR
AMCO PLASTICS**
Made in the UK
Excellent Construction Products

Amflex Wire
Reinforced
and
Layflat
Tunnel
Ducting

Tel +44 (0) 1709 872574
Fax +44 (0) 1709 879020
amcoplastics@naylor.co.uk
www.naylor.co.uk

REFURBISHMENT

TBM REFURBISHMENT

BASA
TBM REFURBISHMENT

Why build a new TBM when you can have a refurbished one? With shorter deadlines, lower costs and more in line with your needs. Think about it. Then call us at +34 946728505.

Pol. Leguizamon, Zuberoa 9, 48450 Etxebarri (SPAIN) www.basatbm.com · info@basatbm.com

RECRUITMENT

Hunter Personnel
Recruiting For Your Industry

Specialists in Tunnelling and
Infrastructure Recruitment

VIEW CURRENT VACANCIES ONLINE AT:
www.tunnelsandtunnelling.com

Contact: David Kellett
T: +44 (0) 1202 298322 E: tt@hunterpersonnel.com
For more information please go to: www.hunterpersonnel.com

**Global Tunnelling Experts.
Bringing the best together.**



Global Tunnelling Experts is your teamwork partner for the best human resource solutions on your tunnel construction site. We supply personnel for all jobs throughout all the construction phases – including operational job profiles for all aspects of mechanized tunnelling operations and the equipment they involve. **Choose the right experts and contact us now.**

Global Tunnelling Experts
+31 (0) 10 266 94 44
clients@global-tunnelling-experts.com
www.global-tunnelling-experts.com
The Netherlands | Germany | United Kingdom
Panama | Denmark | Australia



What's on

2014

Fire Protection and Safety in
Tunnels 2014

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

15th Australasian Tunnelling
Conference

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

BTS Conference 2014

23-24 September 2014
London, United Kingdom
The BTS Conference has risen to become the UK's largest tunnelling and excavation event, and is the only show supported by the BTS.
www.btsconference.com/content

InnoTrans

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

ExpoTunnel

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

facilitated in collaboration with the Italian Tunnelling Society (SIG).
www.expotunnel.it

TAC 2014 Conference

26-28 October 2014
Vancouver, British Columbia
The Tunnelling Association of Canada's "Vancouver TAC 2014: Tunnelling in a Resource Driven World" will include technical sessions and a trade exhibition all designed to highlight advancements in tunnelling research and practice around the world. The TAC Awards and AGM are Monday.
www.tac2014.ca

2015

Shotcrete conference and
exhibition

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

ICETUS 2015

3-5 March 2015
Subang Jaya, Malaysia
Following the successful International Tunnelling and Trenchless Technology Conferences held in Malaysia in 2006 and 2011, the Tunnelling and Underground Space Technical Division of The Institution of Engineers, Malaysia, is holding its third conference to coincide with the massive development of the Klang Valley Mass Rapid Transit.
www.icetus2015.iemtc.com

ISRM Congress 2015

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

World Tunnel Congress 2015

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

RETC

7-10 June 2015
New Orleans, Louisiana
The Underground Construction Association's biennial conference.
www.smenet.org

25th World Road Congress

2-6 November 2015
Seoul, South Korea
The World Road Congress has been held every four years for more than 100 years.
www.aipcrseoul2015.org

British Tunnelling Society

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

Crossrail Western Tunnels, urban
tunnelling through the capital

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

"What could possibly go wrong with a
site investigation in chalk?"

16 October 2014
A review of case histories and the importance of site investigations and particularly the analysis of the results. To include case histories of good and bad practice. The speaker is Rory Mortimer, Brighton University.

Tuen Mun tunnel project in Hong Kong

20 November 2014
Presented by Vincent Avrillon of Bouygues

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

Contact us

Jon Young



Editorial

Editor

Jon Young
Tel: +44 20 7406 6622
jyoung@tunnelsonline.info

Deputy Editor

Alex Conacher
Tel: +44 20 7406 6616
aconacher@tunnelsonline.info

Americas Editor

Nicole Robinson
Tel: +1 612 940 2780
nrobinson@tunnelsonline.info

Regular Contributors

**Adrian Greenman, Bernadette Ballantyne,
Partick Reynolds, Rhian Owen, Danny Richards**

Nicole Robinson



Production

Production Controller

Loraine Lee
Tel: +44 20 8269 7799 Fax: +44 20 8269 7840
llee@progressivemediagroup.com

Technical Illustrator

Nick Stenning

Jim Moore



Head Office

World Market Intelligence
John Carpenter House
7 Carmelite Street
London EC4Y 0BS
United Kingdom

Tel: +44 20 7406 6622
Fax: +44 20 7936 6813

www.tunnelsonline.info
editor@tunnelsonline.info

Sales & Marketing

Head of Sales

Jim Moore
Tel: +44 20 3096 2607
jmoore@tunnelsonline.info

European Sales

Randolf Krings
Tel: +49 611 5324 416
Fax: +49 611 5324 519
rftt@emcmedia.de

Classified & Recruitment

Tom Willard
Tel: +44 20 3096 2608
twillard@tunnelsonline.info

Marketing Executive

Lisa-Marie Ryan
Tel: +44 207 936 6400
lisamarie.ryan@progressivedigitalmedia.com

BTS - Editorial Advisory Board

Editorial Advisory Board Chairman:

Myles O'Reilly ME, PhD, CEng, FICE
Committee: Keith Bowers MSc, PhD, CEng, FICE, MIMMM, FGS; David Court CEng, FICE; Ivor Thomas BEng, LLB, CEng, MICE; Roger Margerison BSc, CGeol, FGS; Barry M New MSc, PhD, CEng, MICE; Roger Bridge BEng; Andrew Smith BSc, CEng, MICE; Ken Spiby BEng; Eddie Woods BSc, CEng, FICE; Petr Salak MSc, Eur Ing, CEng, MICE; Joanne Sui BEng

Subscriptions & Reprints

Subscription prices for 12 (24) months:
Mailed anywhere in Europe €206.99 (€330.99), USA & Canada \$269.99 (\$431.99), UK £126.99 (£203.99), Rest of the world \$275.99 (\$440.99).
Send subscription and back issue queries to *Tunnels & Tunnelling* Customer Services.
cs@progressivemediagroup.com

Tel: +44 (0) 845 155 1845 (local rate)
Fax: +44 (0) 208 269 7277
subscriptions@progressivemediagroup.com
Tunnels & Tunnelling Subscriptions,
World Market Intelligence,
Progressive House, 2 Maidstone Road,
Foots Cray, Sidcup, DA14 5HZ.
Subscribe online at www.buythatmag.com

The content of *Tunnels & Tunnelling International* is subject to copyright. However, if you would like to obtain copies of an article for marketing purposes high-quality reprints can be supplied to your specification. Please contact the advertising team for full details of this service.

Tunnels & Tunnelling International is printed at Stephens & George Print Group, Merthyr Tydfil.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage or retrieval system, without the express prior written consent of the publisher.

The contents of *Tunnels & Tunnelling International* are subject to reproduction in information storage and retrieval systems. Contact: University of Microfilms International, 300 N. Zeeb Road, Ann Arbor, Michigan 48106, US.

Tunnels & Tunnelling International ISSN 1369-3999 is published monthly by Global Trade Media, John Carpenter House, John Carpenter Street, London EC4Y 0AN, UK. The 2012 US annual subscription price is \$ 226 Airfreight and mailing in the USA by agent named Air Business, C/O WorldNet Shipping Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, New York NY 11434 USA. Periodicals postage pending at Jamaica NY 11431.

US Postmaster: Send address changes to *Tunnels & Tunnelling International* C/O Air Business, C/O WorldNet Shipping Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, New York NY 11434 USA.

Subscription records are maintained at Global Trade Media, John Carpenter House, John Carpenter Street, London EC4Y 0AN, UK. Air Business Ltd is acting as our mailing agent.

Tunnels & Tunnelling International and its Editorial Board accept no responsibility for the accuracy of statements or opinion given within the Magazine that is not the expressly designated opinion of the Magazine or its Editorial Board. Those opinions expressed in areas other than editorial comment may not be taken as being the opinion of the Magazine or its staff, and the aforementioned accept no responsibility or liability for actions that arise therefrom.



ALL YOU NEED FOR A COMPLETE TUNNELING CYCLE!

No matter what your challenge is: A small tunnel or a large tunnel, a hydroelectric plant or a subway line, a utility tunnel for heating pipes or for any other purpose. We are specialists in underground tunnels! And we have all equipment you need for a complete tunneling cycle.

www.atlascopco.com

Atlas Copco

Sustainable Productivity



Scan the QR code with your smartphone to watch the Tunneling Cycle movie!