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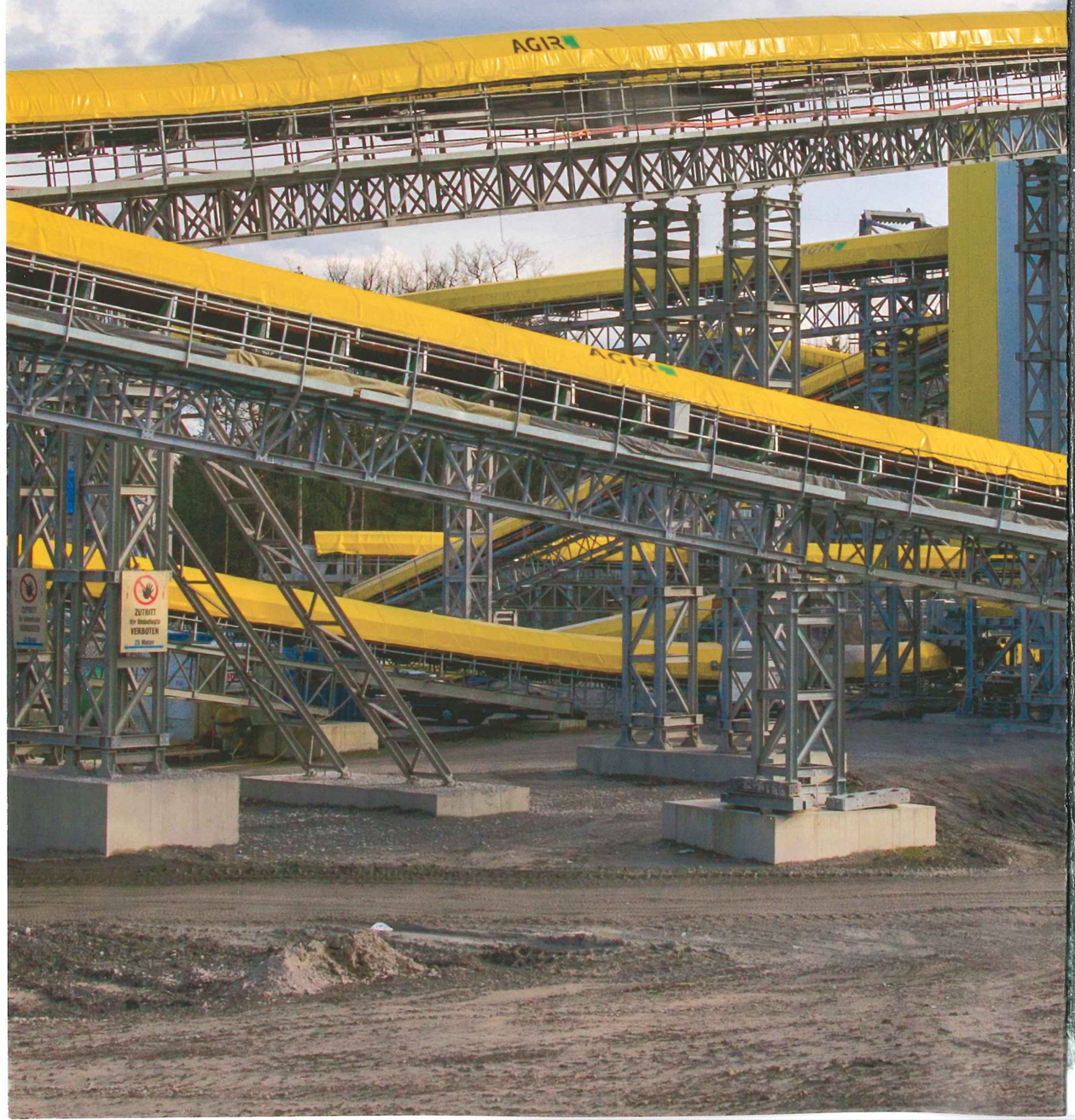
Tunnels AND TUNNELLING

AGIR CONVEYING AT STUTTGART21

The Stuttgart21 Fildertunnel and Steinbühltunnel in Germany are both mucked with AGIR conveyors

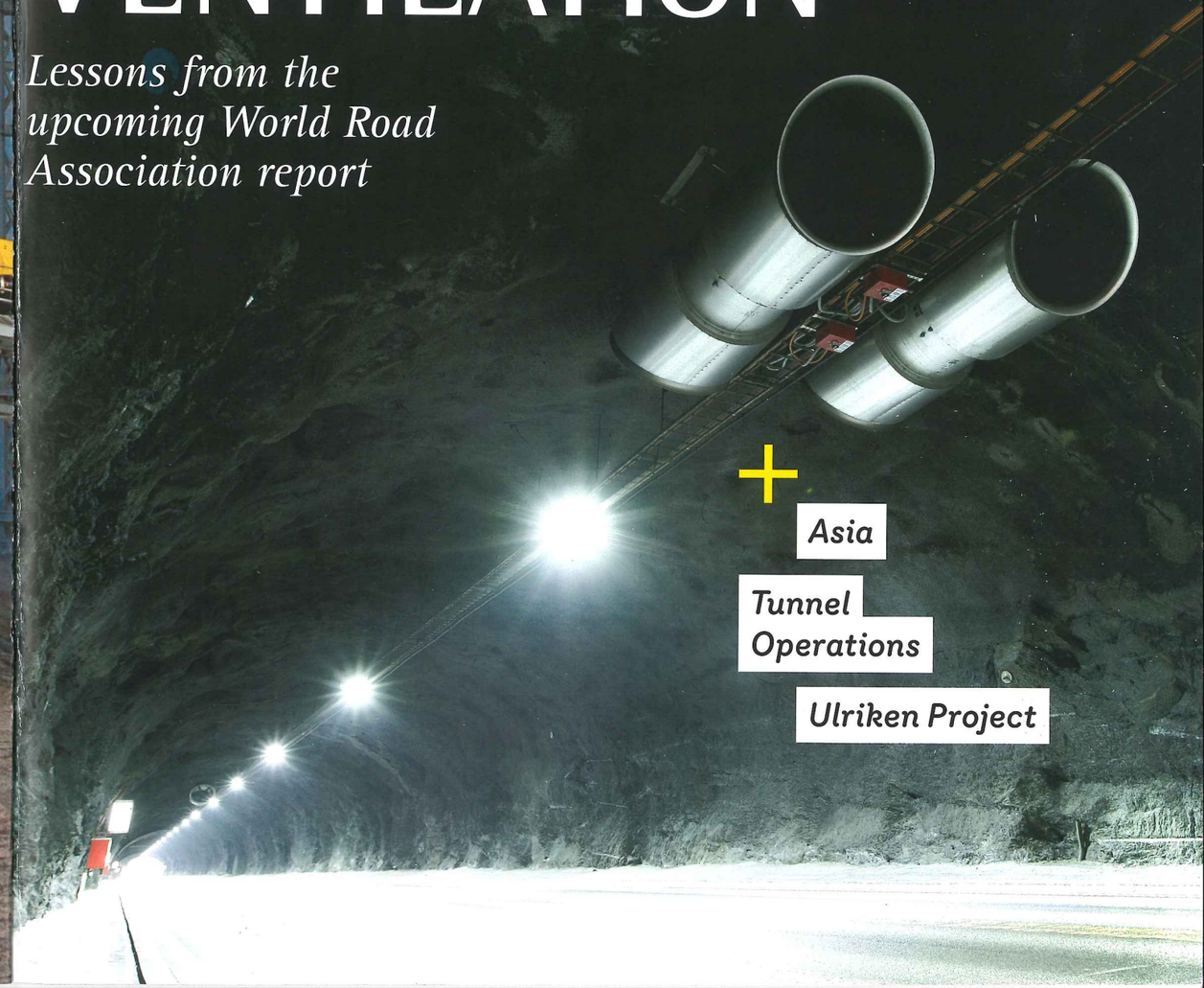


INTERNATIONAL EDITION
November 2015

Tunnels AND TUNNELLING

SUSTAINABLE VENTILATION

Lessons from the upcoming World Road Association report



\+ *Asia*

Tunnel Operations

Ulriken Project

TUNNEL DREAMS

IT'S A HOT Sunday evening in late June. I've got an assignment overdue for work; lectures starting early the following morning, and instead of thinking about either I'm heading to the Warwick University Campus Bar. It's good to be back in further education.

I had joined some 90 attendees for the British Tunnelling Society's Tunnel Design and Construction Course, which takes place over a five-day stretch each summer (for more details on this year's programme, see article, pp.48-49).

Attendees ranged from engineering students curious about underground construction, to young tunnel engineers looking to improve their knowledge of tunnelling concepts, to industry veterans interested in areas outside their particular expertise.

For the most part though, the attendees were young. And among the students, the same reason for attending kept coming up: "I'm desperate for a job in tunnelling". Believe them. The BTS offers sponsorship for up to five university students, which is obtainable by writing a 500-word essay on 'what do you hope to gain from the BTS Design and Construction Course', but others have to pay course fees of the order of GBP 1,400. A definite financial commitment for a student.

A number of students approached me to ask about likely employment prospects; which companies are active, which companies are hiring, who to speak to, and so on. Perhaps companies and recruiters are missing an opportunity here.

The course was excellent (see pp.48-49), and met its aim of "providing a comprehensive introduction to all aspects of tunnelling". It is also clearly popular; the lecture hall would be getting crowded with too many more people attending. But perhaps the wider industry could benefit from a careers segment, or a system by which students completing the course could submit their CVs to BTS Corporate Members, or other interested companies, for consideration.

One of the first activities of the Greek Tunnelling Society Young Members when it formed last year was to append a Career Day on to the Eastern European Tunnelling Conference. The main objective was to bring together tunnelling engineers with companies from Greece and the rest of Europe.

The two-part event began with presentations, first from the companies setting out their work and development plans, then a talk by the ITA Young Members Group on the growing role of young engineers in the ITA. The second part of the event was a networking session between companies and attendees.

Companies involved included: Hill International; Dr. Sauer and Partners; Systra; Geos Ingenieurs Conseils; Geodata; Vinci Construction; Omikron Kappa Consulting; Lombardi; and Pini Swiss Engineers. And speaking a couple of months after the event, a Greek Tunnelling Society member confided that out of the 80 Career Day attendees (it is not know how many applied for jobs), at least 10 were invited to second stage interviews.

This, or a similar approach, might be beneficial in making the course not only a way of passing on knowledge, but also an effective tool to bring fresh labour into the industry.

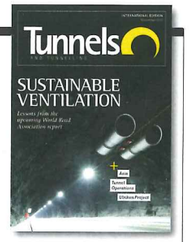
I promised the students that I would pass on the message

editor@tunnelsonline.info

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

Alex Conacher
Editor

Cover
In this issue Fathi Tarada, secretary of PIARC looks at the sustainability of tunnel ventilation systems



Next issue
In the next issue of Tunnels and Tunnelling we will cover the European tunnelling market, with project reports from the Eurasia Tunnel, Crossrail and the Ceneri Base Tunnel. The British Tunnelling Society presentation on Unexploded Ordnance is also featured

This month...

10 YEARS AGO
In the early hours of 2 November, 47 people were evacuated following a collapse on 3.6km-long twin tube Lane Cove Tunnel project in Sydney, Australia. Contractor Thiess John Holland said the 10 x 8m hole was due to an unforeseen geological event that led to rock slippage. A spokesman said that once stabilisation works are complete, an investigation would be carried out.
Tunnels and Tunnelling, November 2005, p.6

20 YEARS AGO
High risks associated with the upgrading of London Bridge Station have forced the Jubilee Line Extension team to adopt hand digging to connect a new station tunnel to the existing network. The work will take place in compressed air through a foamed concrete tunnel. As a result, the southbound Northern Line will be closed for four months next summer, causing major upheaval.
Tunnels and Tunnelling, November 1995, p.7

30 YEARS AGO
What may turn out to be the most expensive science project in history is being planned. A vast circular tunnel, 100km in circumference, looks set to come to the US. Forming an atom-smashing machine called a super conducting super collider, it could cost up to USD 6bn.
Tunnels and Tunnelling, November 1985, p.9

Above: The TBM approaches the face on the Ulriken Tunnel, article on p.46

Key people in this issue

PETER BISHOP
Peter is tunnels technical director for Mouchel. A BTS member, and recently re-appointed Chair of the Road Tunnel Operator Association (see news). He was with Mersey Tunnels for 29 years before joining Mouchel and was instrumental in the design and implementation of DDA compliant evacuation safety systems for both tunnels. In this issue he follows up on an August comment, where he sets out the need to provide emergency egress for those with reduced mobility, with practical solutions and requirements. The article starts on page 33.

ALI MAHDMINA
Ali is Solutions Manager – Infrastructure Objects: Tunnels, Bridges, Locks & Ports for Imtech Traffic & Infra. In this role, he is a manager of engineering processes with product innovation and quality improvement focus. He has spent five years in research and development and has 25 years of experience in rail systems, water/wastewater, petrochemical and road transport industries, in both consulting and contracting positions. In this issue he writes with Peter Bishop on emergency egress for those with reduced mobility, which is a topic the authors' will be presenting at the November 2015 World Roads Congress in Seoul.

WATERVIEW CONNECTION BREAKTHROUGH

NEW ZEALAND — The TBM broke through on the second drive of Auckland's Waterview Connection project last month. Billed by contractor McConnell Dowell as one of the largest TBMs ever used in the southern hemisphere, Alice, the 14.4m-diameter Herrenknecht EPBM completed its 2.4km-long journey.

The NZD 1.4bn (USD 0.95bn) Waterview Connection is New Zealand's largest ever road project. It includes construction of twin three-lane tunnels – the longest road tunnels in the country - and a giant interchange to connect Auckland's Northwestern and Southwestern Motorways (State Highways 16 and 20).

The Well-Connected Alliance JV, consisting of Fletcher Construction, McConnell Dowell, Parsons Brinckerhoff, Beca Infrastructure, Tonkin & Taylor and Obayashi Corporation, is delivering the project. 'Sub-alliance partners' are Auckland-based Wilson Tunnelling and Spanish tunnel controls specialists SICE. Tunnelling first began in 2013 and the first tunnel was completed in September 2014. Alice was then turned 180 degrees to complete her second drive.

Geology was predominantly sedimentary sandstone with average strengths between 1MPa and 5 MPa. There was a small risk that the tunnel would intersect layers of cemented sandstone of up to 120MPa. However, this did not happen.

"The breakthrough is a massive milestone for a project that will transform the way Aucklanders get around their city." said the New Zealand Transport Agency's Highways Manager in Auckland, Brett Gliddon.

"The risks associated with constructing tunnels twice as long as the Auckland Harbour Bridge were always high and the Waterview team rightly needs to be congratulated for its engineering skills and innovation to complete this job safely and on time. That's a fantastic achievement."

Alice is the largest TBM ever used in the southern hemisphere

Work continues, with sixteen cross passages linking the two tunnels still being constructed, as well as M&E fit out. The Transport Agency plans to open the tunnels and the adjacent Great North Road Interchange in early 2017.

Bouygues-UrbaCon chosen to construct sewage tunnels in Qatar

QATAR — The Qatar Public Works Authority has awarded two contracts for the design and construction of sewage tunnels to Bouygues Travaux Publics (a subsidiary of Bouygues Construction), in partnership with a local contractor, UrbaCon Trading & Contracting. The two contracts are worth approximately EUR 550M (USD 617.5M).

Jean-Philippe Trin, Deputy CEO with responsibility for Bouygues Travaux Publics, DTP and VSL, said: "We are proud to have been chosen by the Qatar Public Works Authority.

"For this ambitious project, we have developed an innovative technical solution that will enable us to address the customer's concerns effectively and fully meet their expectations."

In partnership with the local contractor UrbaCon Trading & Contracting, Bouygues Travaux Publics will construct two sewage tunnels in Doha. The north section (MTS01) will be 16km long and 3m wide. The south section (MTS03) will be 14km long and 4.5m wide.

These contracts are part of the strategic project for sewage collection, pumping and treatment services in the south of Doha, known as "IDRIS" (Inner Doha Resewerage Implementation Strategy).

In recent years the Qatari capital has experienced sustained population growth, which has necessitated the redesign and expansion of its sewage system.

On this basis, the Qatar Public Works Authority decided to put in place a modern sewer network made up of large networks of underground collection systems. The system has been designed according to the principles of sustainable development, making use of gravity to ensure the flow of wastewater in the tunnels.

The wide-reaching project began this summer, with handover scheduled for 2019.

Bouygues Construction has been present in Qatar for several years. Bouygues TP constructed liquid gas storage reservoirs in Ras Laffan in the north between 1993 and 1996, while Bouygues Bâtiment International is finishing off its first project in the Emirates, the Qatar Petroleum District, a 700,000m² property complex including nine office towers, a five-star hotel with 400 bedrooms, 5,300 parking spaces, and a conference centre among other facilities.

Two more TBMs deploy on Eglinton Crosstown LRT project

CANADA — The Aecon-ACS Dragados Canada Inc. JV will launch the next two TBMs on the Eglinton Crosstown LRT project on September 29, the Ministry of Transportation announced on September 24.

The 6.5m-diameter TBMs will tunnel westbound starting from the launch shaft located east of Brentcliffe Road. and proceed towards Yonge Street.

"We are making great progress on the Crosstown LRT and I am very pleased that we have reached this milestone," said Steven Del Duca, minister of transportation. "By providing light rail transit across the city, we will help thousands of commuters get where they need to be quickly and easily. The Crosstown LRT is further proof of our commitment to manage congestion, keep the region moving, and improve the quality of life for Ontarians."

Work on the western segment of the tunnel has been underway since June 2013 with four of the 6.5km already complete. All tunnelling work is expected to be finished by the end of 2016.

"The Eglinton Crosstown will not only transform the transit landscape for Toronto residents, but it will also help improve connections to the region's transportation system," said Bruce McCuaig, president and CEO of Metrolinx. "The progress we're making on this project is a true reflection of the important transit investments being made in the Greater Toronto and Hamilton Area."

The Eglinton Crosstown LRT will be in service by September 2021 and will include 19km of light rail transit along Eglinton Avenue, including 10km underground.

ITA PUBLISHES STRATEGY FOR SITE INVESTIGATION OF TUNNELLING PROJECTS

INTERNATIONAL — The International Tunnelling Association (ITA) has released a new publication, its 'Strategy for Site Investigation of tunnelling projects'. The document has been prepared by Working Group Two – Research.

In a statement, ITA announced: "This study of site investigation for tunnelling projects began with a request from the Executive Council Meeting held in Kyoto, Japan on November, 2001 led by Professor Andre Assis, former President of the International Tunnelling Association (ITA).

"As it is not possible to predefine the ground conditions in detail before a tunnel is constructed geological risks exist on any tunnelling project. The purpose of site investigation is to provide adequate and reliable information in early stages of the project in order to improve the knowledge of the subsoil, assess various design options and choose construction methods that better cope with the identified potential risks.

"Site investigations have to be conducted within the global strategy of project risk management (see "Guidelines for Tunnelling Risk Management", WG2, 2004) and should follow the ALARP (as low as reasonably practicable) principle to reduce risks - namely geological, geotechnical and also hydrogeological risks.

"The level of acceptable risk as defined by the ALARP principle can be specified in different ways depending on the design stage, and the site investigation strategy should take cognisance of this. The effort required during a site investigation (in terms of the scope of investigation and related cost) will vary with the project development, and has to focus on progressively improving the level of knowledge. The effort required at any stage will depend upon the complexity of the project and will have a direct impact on risk mitigation and project cost.

"This document presents the strategy for site investigations based on international best practice, with the aim of maximising the benefit in terms of acquiring knowledge at the right project phase, while avoiding common misleading approaches in terms of investigation effort and responsibility. It is hoped that this document will be a useful guide for future tunnelling projects."

The document can be found through the following link: *www.ita-aites.org/en/publications/wg-publications/download/1373_c23b267187260e75764d4a39728328aa*

Excavation completes on first Riyadh Line Five tunnel

SAUDI ARABIA — Spanish contractor FCC announced last month that it had broken through into Salah Al-Din Station after a 1.2km drive with its 9.77m TBM 'San'ah'. The total section of work, on the northern portion of the green line, comprises 5km.

The 'FAST' consortium undertaking the work, and led by FCC, also includes Samsung C&T, Alstom, Strukton, Freyssinet Saudi Arabia, and Atkins.

An FCC spokesman said, "The drilling works, which began on 30 June 2015 at the new central office for the Ministry of Education, will continue on the north section of line 5 (green line) until they reach Riyadh Airbase Roundabout. There they will be met with our other 9.77m TBM 'Dhafrah', the first machine to start drilling works on the Riyadh Metro project, which will be used to finish the [full] 12.9km tunnel of Line Five."

Work is expected to complete in late 2018. FAST received a USD 7.9bn contract to construct and design lines Four, Five and Six of the metro. The scope of contract includes construction of 64.6km of rail track, 29.8km of viaducts, 26.6km of underground, and 8.2km of overground track.

Breakthrough on the first stretch of tunnel

Brian Garrod named Canadian Tunneller of the Year 2015

CANADA — Brian Garrod has been named Canadian Tunneller of the Year by the Tunnelling Association of Canada (TAC). Garrod is executive vice president and practice lead for tunnels with Hatch Mott MacDonald. He began his career as a contractor in the UK, before moving to Hatch in Canada in 1974.

Regarding his award, the TAC stated, "Brian has always been passionate about tunnelling and his zeal has inspired many tunnelling professionals. He has motivated and mentored aspiring tunnellers through participation in industry workshop panels, peer reviews, and the presentation of numerous technical papers. He has earned professional respect among his peers due to his technical excellence.

"An active member of the Tunnelling Association of Canada (TAC) since 1984, he also served as Director of the Ontario Chapter and was TAC's National President for four years. Brian's contributions to the Canadian tunnel industry, along with countless hours spent volunteering with TAC and others to actively promote the practice of tunnelling to aspiring engineers and providing much needed mentoring to strengthen the supply of future tunnel engineers makes him a most deserving candidate for the 2015 TAC Canadian Tunneller of the Year award.

"As he enters retirement, the prestigious TAC award would be an appropriate and fitting testament to his contributions to the tunnelling industry."

Garrod said, "I am tremendously honoured to receive this award. To be in the company of the previous industry-leading recipients of this award represents the pinnacle of my career.

"It is wonderful to be rewarded in this way by an industry that I love, and to which I have dedicated most of my working life.

"What an industry this is, where the son of a farm worker can reach such dizzying heights.

"This industry is a remarkable equaliser bringing together academics, designers, manufacturers and contractors to the same learning experiences."

HMM/MWH to design Westerly tunnel in Cleveland

USA — The Northeast Ohio Regional Sewer District (NEORSD) has chosen Hatch Mott MacDonald, in a joint venture with MWH Global, for a major contract to design the Westerly Combined Sewer Overflow (CSO) Storage Tunnel and Dewatering Pump Station in Cleveland, Ohio, HMM announced in October.

The Westerly Storage Tunnel will help prevent combined sewer overflows by providing 36 million gallons of storage. The tunnel will be built beneath the Ohio City neighborhood west of Downtown Cleveland, and will capture 98 per cent of the annual combined sewage in the Westerly District.

With a construction value of approximately USD 200M, the project also includes the design of a new Tunnel Dewatering Pump Station to dewater the tunnel to the existing Westerly Wastewater Treatment Center on Lake Erie. "This is the same JV that successfully designed the NEORSD Dugway CSO Storage Tunnel, which is now under construction. Prior to that, HMM was the design lead for the award-winning Euclid Creek Tunnel, which is also in construction and scheduled to be completed later this year. We are proud of the work we have done with NEORSD, and we are pleased to be collaborating with them on another important project," said Nicholas DeNichilo, president and CEO of HMM.

Skanska scoops Norwegian road tunnel

NORWAY — Skanska has signed a contract with the Norwegian Road Administration (Statens vegvesen) to build Sørkjosfjelltunnelen on the E6 in Troms, the company announced on 7 October.

The contract is worth NOK 435M (USD 53.4M), which is included in order bookings for Skanska Norway for the third quarter of 2015. The contract includes the completion of the 4.6km-long tunnel and improvement of 1.5km of road. The project has already begun and is expected to be completed in July 2018.

Road Tunnel Operator Association to become Road Tunnel Association

GREAT BRITAIN — The The Road Tunnel Operator Association (RTOA) is set to become the Road Tunnel Association (RTA). Mouchel's technical director for tunnels and engineering Peter Bishop has returned to the association as chairman to manage the transition.

Bishop told Tunnels and Tunnelling that so far the membership of the RTOA has been restricted to representatives of each tunnel owner and their managing agents or companies, tunnel safety officers, tunnel managers and a number of honorary members who have served the RTOA previously. "The name change is to broaden membership, beyond just 'operators' and invite consultants/ experts in Tunnel related specialities and others with an interest in how tunnels in the UK and Eire are managed, to participate. We are also hoping to target more young members. We are not looking for commercial interest, those in sales of a particular product. Like the BTS the RTA aims to be a learned society."

Bishop added that there has been a desire to ensure that knowledge and experience in areas such as tunnel operation, tunnel safety, ventilation, training and qualification structure, asset management, M&E systems, tolling, among others is not lost to the association as people move out of the tunnel management industry.

Administrative details such as a new organisation badge and address, website changes, financial admin, and constitution amendments, as well as other documentation changes are required, after which it has been agreed that Tony Killen, head of asset management at Merseytravel will succeed Bishop as chair.

In other RTOA news, the association is hosting an official visit for a delegation of tunnel designers, managers, and operational directors from Shandong in China, at the end of November. They are inviting the delegation to see how UK tunnels are run.

BREAKTHROUGH AT LAL QUILA

INDIA — The TBM boring from Kashmere Gate to Lal Quila in Delhi has completed its journey. Part of Delhi Metro Phase III, contract CC-07 forms part of the extension of the Central Secretariat corridor to Kashmere Gate.

The contractor is a joint venture comprising Russia's Metrostroy and local firm ERA Infra.

A Delhi Metro Rail Corporation spokesperson said: "This TBM was lowered at Kashmere Gate shaft on 6 December 2014 and after assembly of the TBM below the ground the initial drive began on 26 December 2014. The maximum depth of the tunnel is 16m below the earth's surface."

The 6.61m-diameter EPBM was manufactured by Terratec. It is kitted out with 33 no. 17in disc cutters and it has excavated 1,351m, and another TBM was still working on the 1,356m-long parallel bore as Tunnels and Tunnelling went to press. Under the Delhi Metro Phase-III plan, the Violet Line is being extended from its current terminus to meet the Yellow and Red Lines at Kashmere Gate Station. This will offer an alternative route between Central Secretariat and Kashmere Gate Stations, easing crowds

Breakthrough was achieved at the Delhi Metro CC-07 reception shaft

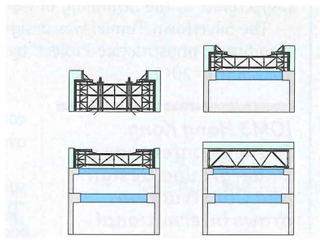
Capitol Hill Station, Seattle, USA

Kevin Whalen, Superintendent
Turner Construction, Seattle

"Working in collaboration, PERI and Turner Construction designed the Traveling Mono System which has met scheduling and budgetary constraints. We've increased the level of safety for our workers as well as reduced the number of man hours required to set up traditional formwork systems. This system was specifically designed to pour concrete from the ground to the roof giving us ability to maximize our labor force and allow subcontractors to work beneath the system, all while improving on the quality of the finished product."

The formwork solution is based on system components of the VARIOKIT engineering construction kit. The traveler system for the bottom level is also used in the upper levels.

The VARIOKIT traveler system rolls from one section to the next on rails after each pour, without the formwork having to be broken down and reassembled.



The three levels of Capitol Hill Station have been poured one after another – using a clever designed traveler system that is moved on rails from one pouring section to the next.

SILVERTOWN TUNNEL PUBLIC CONSULTATION OPENS

GREAT BRITAIN — Public consultation on the Silvertown Tunnel opened last month. The project would be a new crossing of the Thames River in east London. And would provide much needed relief of congestion at the Blackwall Tunnel which on an average day experiences 3km traffic jams during peak periods.

The public consultation runs until 29 November 2015 and will form part of TfL's submission for a Development Consent Order to the Government for permission to start construction. The construction is expected to begin in 2018 with the new tunnel fully operational by 2022/23.

The alignment itself cannot be changed too much however as some recently built structures anticipate a tunnel, not least a viaduct on the DLR extensions, which sets its piers wider apart at this point, and the cable car, too, which has foundations nearby.

Next steps for the project are due this summer, he says. Under the DCO process the statutory consultation can be relatively short - though about eight weeks are allocated rather than the minimum four. There was a 10-week local public consultation last year as well.

An application may be submitted to the Planning Inspectorate at the beginning of next year.

The Silvertown Tunnel was designated a 'Nationally Significant Infrastructure Project' by the Secretary of State for Transport in 2012.

IOM3 Hong Kong Branch conference on Underground Design and Construction draws international attendance

HONG KONG — On 11 and 12 September, over 350 Delegates converged on Hong Kong to partake in the second IOM3 Underground Construction Conference organised by the Hong Kong Branch (www.UDCC2015.com), the last one being held over five years ago.

Bruce Matheson, FIMMM, summarised proceedings: "Delegates mainly comprised local engineers but there was also a significant international contingent, including a sizable contingent from the Copenhagen Metro.

The papers covered a multitude of subjects, with keynote papers from Nick Barton (Nick Barton and Associates), C. F. Lee (University of Hong Kong), Lok Home (Robbins) and Martin Herrenknecht (Herrenknecht) and with other papers covering matters from technical design issues to case studies. All of the presentations were well received by the enthusiastic crowd.

"Congratulations should be extended to the conference organisers, the Hong Kong Branch of the IOM3."

For more information on IOM3 (Hong Kong Branch) or the Hong Kong Tunnelling Society please email Secretary@iom3.org.hk or come along to the Mariners Club on the last Friday of each month.

Orginisers and some speakers gather at IOM3 HK

Tunnelling VPs appointed at WSP PB

USA — WSP Parsons Brinckerhoff has named Steve Klein and Steve Dubnewych vice presidents of the firm's tunnelling practice in California, it was announced September 22.

"With these two stellar additions to our team, we reinforce our leading position in tunnel engineering in California and the rest of the country," said George Munfakh, director of the firm's geotechnical and tunnelling technical excellence centre.

Klein, who will be based in the firm's Sacramento office, has more than 35 years of experience in the planning, design and construction of tunnel projects throughout California and the US.

He has led the design of tunnel projects with construction values ranging from USD 100M to more than USD 5bn including tunnels for water supply, wastewater, hydroelectric power, highways and mass transit and.

Prior to joining WSP Parsons Brinckerhoff, he was the California regional manager for another international engineering firm, responsible for managing offices in San Francisco, Pasadena, San Diego and Walnut Creek.

Klein received an M.S. in geotechnical engineering from the University of California, Berkeley and a B.S. in geotechnical and structural engineering from the University of Illinois, Urbana-Champaign.

He is a member of the American Society of Civil Engineers, American Society for Testing and Materials, American Water Works Association, and North American Society for Trenchless Technology.

He is a registered professional engineer in California and four other states.

Dubnewych will be based in Los Angeles and will lead the company's Southern California tunnelling practice and support projects globally, particularly those related to water conveyance.

He has 28 years of tunnelling experience, including work on tunnels for highways, transit, wastewater, water supply and hydroelectric generation.

Prior to joining WSP Parsons Brinckerhoff, he was a principal in the Los Angeles office of an international engineering firm, responsible for managing design and construction activities for a variety of highway and water\wastewater conveyance tunnels in Southern California.

Dubnewych received a B.Sc. degree in mining engineering from Queen's University in Ontario, Canada.

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

editor@tunnelsonline.info

CONSTRUCTION SKILLS CERTIFICATION SITES ACCUSED OF FOUL PLAY

ALLEGATIONS OF corruption were laid against the Construction Skills Certification Scheme (CSCS) last month. A BBC undercover investigation revealed what it called "widespread, organised cheating, allowing untrained builders on to dangerous sites". CSCS cards are often required to prove knowledge of health and safety. Many companies demand employees have them, Crossrail included.

CSCS released a statement in response to the accusations: "CSCS takes the issue of fraudulent activity extremely seriously and it is essential that steps are taken to prevent it. It is important to note that CSCS is not responsible for developing qualifications or delivering construction industry training.

"CSCS relies on the Awarding Organisations (approved by qualifications regulator OFQUAL) to monitor the performance of their approved training providers and to verify that an individual has achieved the required qualifications before CSCS issues a card.

"CSCS works closely with the Awarding Organisations, CITB, HMRC, the Police, Trading Standards and other agencies to identify and take action against those attempting to deceive construction employers. CSCS is confident the vast majority of cards issued are a result of obtaining a qualification legitimately. In cases where the awarding organisations inform CSCS that a card was obtained fraudulently the card is cancelled immediately and action taken against individuals and organisations attempting to deceive construction employers.

"It is CSCS's firm belief to ensure UK construction sites remain safe, construction site workers must have legitimate training and qualifications before allowed to work on site.

"CSCS will continue to share intelligence and work with the authorities when the evidence suggests criminal activity is taking place."

TunnelSkills Forum Chairman Tom Lane spoke with Tunnels and Tunnelling as the story broke. TunnelSkills does not make use of the CSCS centres currently being investigated by the BBC, but Lane saw a wider issue with the scheme.

"Personally, I think that one of the problems associated with the CSCS card scheme is that a lot of people don't understand what it actually is and how it should link card holders to the occupation on the card via a recognised competence based qualification, academic qualification or any other defined criteria associated with the required occupation/card.

"Too often people mix up the H, S&E test and the card and assume that the test defines the card. The test, however, is only part of the application process with the occupation/type of card defining the type of test that needs to be taken and achieved. The H, S&E test purely benchmarks safety knowledge at the level at which the test is taken; it does not define competence.

"CSCS could help itself maybe by simplifying the scheme a bit and looking at modernising it and aligning it to new technologies and information systems.

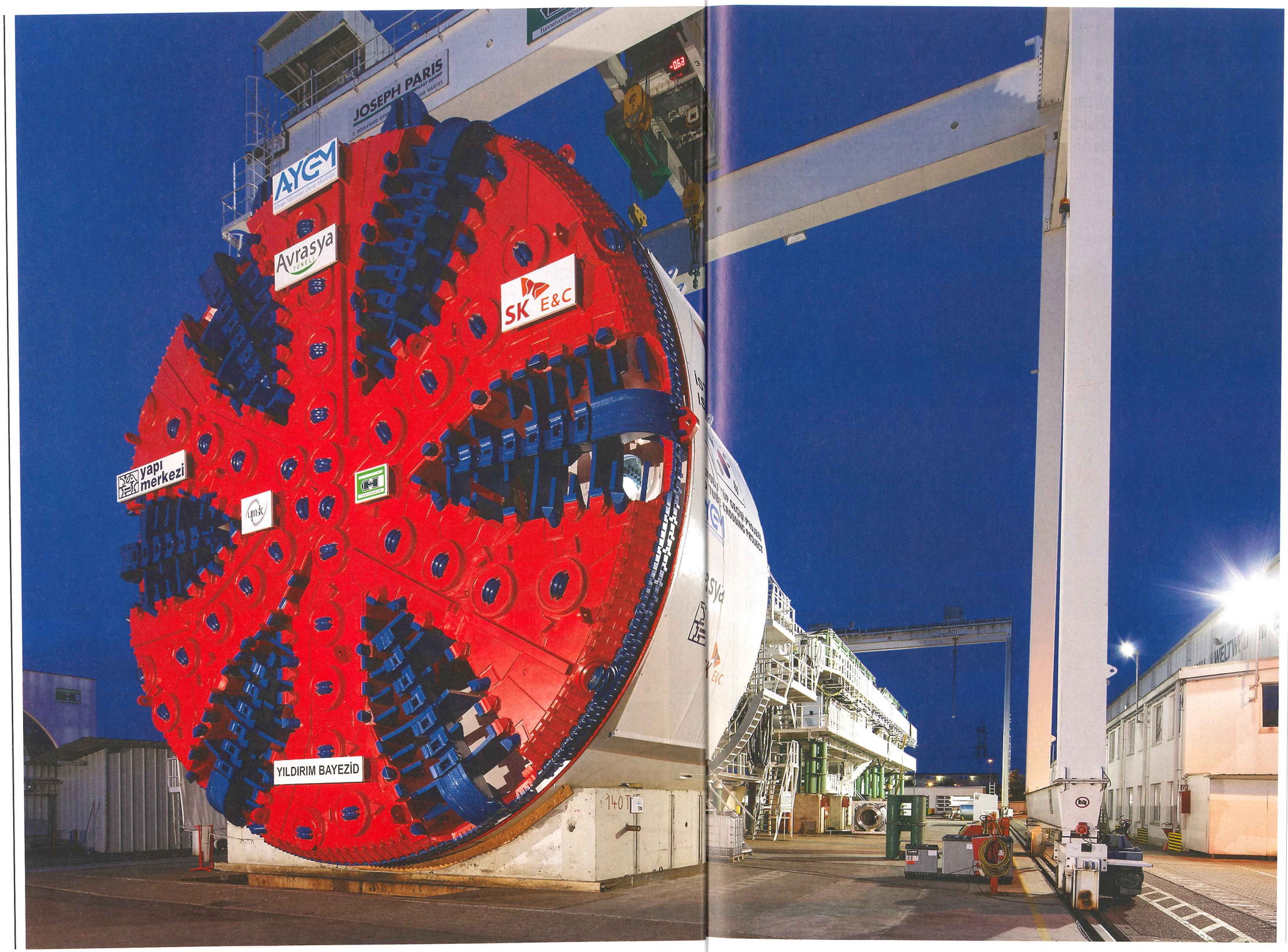
"It also needs to educate the industry better about what it is and encourage more people to use the website which is a very useful tool for explaining the scheme and understanding the application process.

"The industry also needs to get its act together; it needs to encourage the appropriate people to better understand the scheme. It needs to stop asking the question 'Have you got a CSCS Card?' and move to the question 'Have you got the appropriate CSCS card for your job role?

"And finally, it needs to stop migrating to the easiest option for getting a CSCS card. CSCS are currently removing some of these 'easy options'.

"Unfortunately, it will always be difficult to stop unscrupulous people circumnavigating the system"

Below: CSCS cards are taken as proof a worker can act safely end effectively on site



Left: The 13.66m-diameter Herrenknecht Mixshield that broke through on the Eurasia Tunnel project was assembled and tested at the Herrenknecht plant in Germany. One of the technical innovations is an accessible cutting wheel for safe replacement of the excavation tools under atmospheric conditions. Special lock systems allow interventions at up to 11 bar ambient pressure

IN THE PINK

A treacherous under passing of an historical gate in Jaipur is the key challenge on the city's first venture into underground mass rapid transit. **Alex Conacher** speaks to **Chris Cooper** of contractor *CICI* and **Jim Clark** of manufacturer *Robbins*

THE 'PINK CITY' of India's Rajasthan State, Jaipur is five years into its first mass rapid transit project: the Jaipur Metro. Appropriately called the Pink Line, this elevated route entered operation in June. And already an extension is underway.

As with many Indian metro projects, the decision to go underground is only made when essential. Jaipur is no exception. The extension to the Pink Line is tunnelled, but only because it passes under the historical Chandpole Gate into a heritage area of the city.

The elevated section of the Pink Line ends some 120m short of the gate, which also marks the start of the twin-bore TBM drive from the existing Chandpole Gate terminus, to the new end of the extension at Badi Chauper.

***Above:** The Chandpole Gate, marking the entrance into the historical district of Jaipur*

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

PROJECT OUTLINE

This extension, Phase 1B of the Pink Line, calls for 2.3km of twin bore tunnel at 5.8m internal diameter, lined with a 5+1 275mm-thick tapered ring; and two underground stations to be constructed by contractor CICI. Two Robbins EPBMs set up for soft ground conditions were refurbished from the contractor's previous job on Delhi Metro's Phase Two: package BC-16.

Geology consists of alluvium silty sand along the entire length, with some gravels (but not in consolidated patches) and the bore is entirely above the water table. These conditions are similar to the Delhi package, but a curve with a 392m radius prior to reaching the gate called for active articulation capabilities, whereas the previous job was just a straightforward drive. Jim Clark, Robbins project manager adds: "It's quite a big job, cutting the machine in half around the centre section, putting another section in and forming the articulation joints. The parts were made overseas and installed at the contractor's casting yard in Jaipur. We also installed a new a+b grouting system and an Enzan Tunnel Guidance & Logger System for position monitoring."

The two stations will be constructed top-down after the TBMs have passed through the stations' diaphragm wall framework, which will be complete before they arrive.

Overburden will range from 5.8m after the launch shaft then a constant downwards alignment to about 10m at the reception shaft. But the real challenge comes during the underpassing of the Chandpole Gate, its foundations just some 4.5m above the crown of the TBM.

GATE APPROACH

Chandpole Gate is 97 rings into the drive according to CICI project manager Chris Cooper, and the Zone of Influence is 10 rings either side. This is just enough time to get used to the boring parameters and make sure settlement is under control to pass the gate within the 5mm trigger levels.

However, there were initial concerns. "We only have one diameter (or less) above the tunnel," says Cooper, "and when we launched we experienced some friction over the top of the machine, which dragged the ground forward and caused heave."

Robbins' Clark says, "On the alignment leading up to the gate we had monitoring points every 1m and we were getting heave of 25mm or more in places. The soil completely lacked elasticity, which combined with the low overburden, was causing the heaving. Clay is forgiving, but this silty sand is not. There was a bit of trial and error to get everything in balance."

The teams had launched the first machine on umbilicals due to the small launch shaft, and the plan was to approach the gate, stopping short of the Zone of Influence, before dropping down the backup gantries. During this initial phase of boring, there was leeway to experiment with trial and error, and it was seen that when the articulation was used for vertical steering, it was worsening the ground heave.

Cooper says, "To solve this we basically put the articulation back into line, and we injected bentonite through the skin to reduce the friction between the sand and the TBM skin. We also opened up copy cutter slightly, to have some broken ground around the machine and again reduce friction."

Project vitals

- **Tunnel length:** 2.3km twin
- **Diameter:** 5.8m id
- **Civil engineering value Phase 1B:** INR 5bn (USD 77M)
- **Total metro cost:** Approximately INR 97.32bn (USD 1.74bn)
- **Geology:** Alluvium, silty sands with unconsolidated gravels
- **Contractor:** CICI
- **Consultant:** Omikron Kappa-Indus Consultrans JV
- **Excavation method:** EPB TBM
- **Lining type:** 5+1 concrete segmental lining, 1.2m wide, 275mm thick
- **Shaft dimensions:** 22x25m

Machines

- **Type:** EPB
- **Diameter:** 6,550mm
- **Maximum thrust:** 14,500kN
- **Cutterhead drive:** VFD electric motors
- **Cutterhead power:** 810kW (9x90kW)
- **Cutterhead speed:** 0-3rpm
- **Working torque:** 2,479kNm
- **Screw conveyor:** 840mm
- **Belt conveyor:** 914mm
- **Length:** 73m

***Below:** Lowering TBM components into a shallow launch shaft*

PASSING THE GATE

The client requires that experienced expat drivers and supervisors operate the TBMs when they are within the

Timeline

- **Contract award:** mid 2013
- **First ring:** 28 May
- **First bore complete:** May 2016
- **Second bore complete:** August 2016

gate's Zone of Influence. CICI employs a skilled but young crew of local engineers with expat managers and supervisors, so control of the TBMs during this time was given to Robbins.

In India this can be a common procedure, with some sites having as many as 200 manufacturer personnel undertaking work, and others having just one or two supervisors. In this case, 18 were employed.

Clark elaborates on the work: "Due to the low cover we experienced heave of up to 25mm over the TBM when using the articulation for steering, so we closed up the articulation, and reverted to steering the machine traditionally, by use of the main thrust cylinders and copy cutters. Bentonite was injected around the shield to reduce the frictional forces between the ground and TBM. We gradually improved the settlement performance with boring parameter tweaks and settled on face pressure at 0.9 bar, cutterhead rpm at 0.8 and thrust pressures around 22,000-26,000kN.

"We kept an eye on settlement with real time monitoring and managed to achieve values of plus/minus 2mm which was a big improvement from 25mm. Because it was a short startup shaft and we were working on umbilicals we could only use one muck car rather than the four cars required to complete a 1.2m ring. So, we bored 400 mm, and then took readings on the surface along the alignment. This information would was then fed back to us and we'd tweak our operating parameters accordingly"

Cooper adds: "It was an extensive investigation into the ground and gate foundations and a couple of additional consultants got involved. The engineers got the parameters that were needed, and then went through."

The second machine will pass under the gate at 14.6m (centre line to centre line) from the existing bore so interaction is not expected.

PROGRESS

As Tunnels and Tunnelling went to press, the first TBM had produced 200 rings and was safely beyond the gate. The first permanent ring was formed on 28 May of this year. The second machine was due to launch in mid-October. According to Clark, with a bit of luck tunnel excavation will be finished on the first bore by May 2016, and the second three months later.

With excavation now moving beyond the main challenge on the first bore, and the second bore expected to proceed in much the same way, a successful completion seems likely to the teams.

Logistics are still a laborious challenge in the busy city, and site supply and muck removal can only be undertaken at night, but as Jaipur was the first planned development layout for a city in India, this is not as onerous as it might be. The city was built in 1724 with an American style grid system, and the site footprint rests in one of these crossroads.

The teams are currently still boring with one skip and best performance has been 10 rings in a day. Some 300m per month average is expected.

OPERATION

According to Tunnels and Tunnelling sister publication Railway Technology, Bharat Earth Movers Limited (BEML) was awarded a INR3.18bn (USD 57M) contract in December 2011 to deliver ten four-car train-sets for the Phase 1 of Jaipur Metro. The first train-set was rolled out at BEML's factory in Bangalore in April 2013. It is the first indigenously designed and manufactured electric multiple unit by an Indian company.

Below: TBM preparing to launch off a frame

Alstom was awarded a contract by DMRC in April 2012, to supply an Urbalis train control system to EW-A section of the new Jaipur metro Phase 1. Alstom is responsible for the design, production, installation, testing and commissioning of entire train control, traffic management and signalling systems under the contract. Urbalis is an automated train operation and traffic management system allowing safe and energy-efficient train services on the metro rail network.

Thales received a contract from DMRC in April 2013, to supply an advanced passenger information system for the Jaipur Metro. The Thales passenger information system can be integrated with the traffic management system and will deliver accurate visual and audio information to passengers

SPRING TO ACTION

An overview of works required for Thomson Line contract T208 as TBM launch completes. **Alex Conacher** speaks with the John Holland Leighton Asia JV

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

AT THE time of writing the Leighton John Holland joint venture was in the process of completing the second launch of its three NFM slurry TBMs on contract T208 of Singapore's Thomson Line for the Land Transport Authority, Singapore. The first of three TBMs for the project, named Hera after the Greek Queen of the Gods, was successfully launched on 20 August. The second TBM was named Luna after the Goddess of the Moon. Luna was delivered to site in July and was launched late in September. The third TBM, named Memera, after the Greek Goddess of the Day, arrived in Singapore on the 8 September with assembly planned to commence in late October.

The T208 contract, the award of which was announced in November 2013 for a sum of SGD 383M (USD 275M), covers the line's Springleaf Station and associated tunnels, and is located in the northern portion of the new 30km-long line. T208 is one of 23 main contracts to deliver the line.

The launches were momentous occasions (according to LTA) heralding the start of tunnelling on what will be the sixth Mass Rapid Transit (MRT) and the fourth fully automated and driverless system line in Singapore. There will be 38 TBMs required for Thomson Line and Contract T208 has three of these. The TBM launch was marked by a special blessing ceremony to provide good luck and safety to the workers throughout the six month excavation.

WORKS REQUIRED

A cut and cover secant bored pile wall box ('Tagore' in the diagram) is to be excavated, measuring 170m long x 28m wide x 20m deep, for launching TBMs and future use as a station.

As for tunnels, twin 1.12km bores from the Tagore box to Lentor Station (Contract T209 - one stop south of Springleaf Station) with the water table 5m to 20m above the crown through 95 percent Bukit Timah Granite grade IV-VI (5 percent mixed face), with three cross passages and extensive ground treatment for residential building projection at one stage near Florrissa Park. This was completed with deep cement mixing and is due to shallow cover beneath residual soils.

In the other direction from the Tagore box towards Springleaf Station, twin 1.07km tunnels with similar water table conditions, but through 50 percent Bukit Timah Granite grade IV-VI and 50per cent rock and mixed face conditions. Three cross passages and two in-line sumps passing beneath the Seletar Expressway (SLE) and 7.4m above the Deep Tunnel Sewer System tunnels (DTSS).

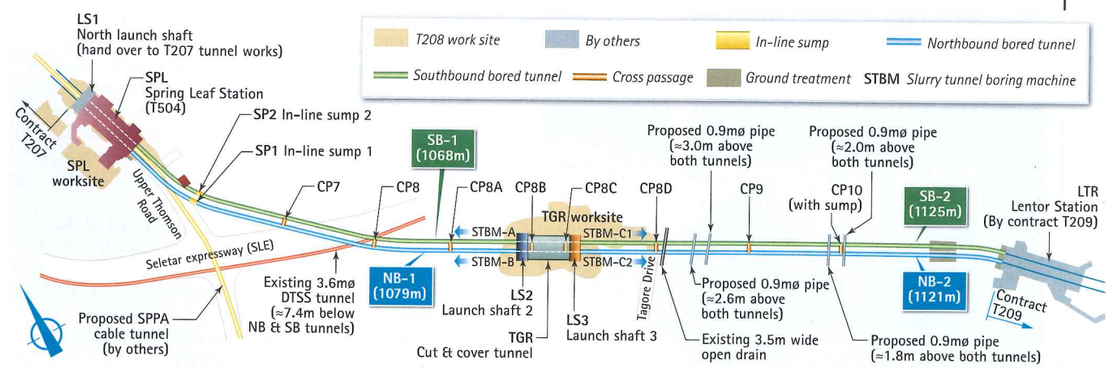
The first TBM, Hera, will execute two of the drives, so there was not a need for a fourth TBM.

At Springleaf Station, a temporary diaphragm wall box with three entrances and one ventilation shaft, and including a launch shaft for an adjacent contractor's TBMs measures 180m long x 20m wide x 20m deep. It needed extensive recharge well installation. Springleaf Station is in Bukit Timah Granite grade IV-VI with sections of grade III weathered rock and corestone.

The client designed all permanent works; temporary works were designed by the joint venture's temporary works designer.

LINING DESIGN

A standard LTA-designed reinforced segmental lining 5+1 configuration is being used. The tunnels have a 5.8m internal diameter, with segments



Below: ***Scope of works for the T208 project***

275mm thick, ±20mm taper with left and right hand rings, 40mm cover, 60MPa concrete, and three rebar designs for various sections of tunnel. The lightest rebar is used in the rock section, the heaviest near the structures and shallow cover, and the medium weight in the full Bukit Timah Granite grade IV-VI weathered zones.

All segmental lining is epoxy-coated externally for durability. Segments are produced at a casting yard in Malaysia and transported to Singapore. Korea Moulds manufactured the moulds.

*Above: **Blessing ceremony held on 31 July to ensure a safe journey for Hera***

*Below: **Tagore site STP spoil pit showing initial excavation after tunnelling through fibre-glass reinforced piled wall***

Schedule

Completion of the whole of the works: 2020

GROUND TREATMENT

The joint venture employed two ground treatment contractors for the project to perform fissure and jet grouting at Springleaf for diaphragm walls and intervention blocks, as well as deep cement mixing for ground stabilisation within the diaphragm walls at Springleaf, also for protection from the cable tunnel beneath, and at the shallow cover section near Florrissa Park mentioned above. There is also jet grouting for the cross passages and launch/reception blocks.

KEY CHALLENGES

The team expects the main challenges to come from the ground conditions, which vary from 220MPa granite to soft ground and cross passages needing extensive ground treatment. Although other challenges include traffic diversion and local community/working hour controls. The contractor has a full-time Public Relations Officer and gets involved in frequent communication with the stakeholders, including shopkeepers and residents. The TBM naming ceremony was also shared with both the local community and adjacent contractors in the area.

The main list of existing assets to be considered is: the Seletar Expressway (SLE), Deep Tunnel Sewer System tunnels (DTSS), Florrissa Park residential area, Singapore Power cable tunnel (passes beneath Springleaf Station and the T208 tunnels elsewhere pass it over).

Regular meetings are held with the neighbouring T207 contract to ensure things run smoothly

OPERATIONS FOR DESIGNERS

Andy Evans, immediate past chair the *Road Tunnel Operator Association (RTOA),* discusses tunnel operations for designers of tunnel life safety systems designers

Andy Evans
Andy is the immediate past chairman of the Road Tunnel Operator Association

WHAT IS a tunnel operator? In the UK, the term 'Tunnel Operator' is variously used to refer to the organisation responsible for managing the risks arising from traffic using the tunnel (traffic risk) through to the people who work in the control room or manage the maintenance of the tunnel – and everything in between. The difficulty with defining a tunnel operator is that in the UK we have very many different organisational models of tunnel operation. They range from organisations that employ dedicated teams responsible for all (or most) aspects of tunnel operation (traffic, equipment, renewals, emergency response etc) through to organisations that 'operate' unmanned tunnels – the role of these 'operators' often being to maintain the tunnel and tunnel systems. Within this range, the global risk management provided by the operator ranges from comprehensive to negligible.

When a designer of tunnel life safety systems (within life safety systems the author includes all equipment and systems necessary to create a safe environment for tunnel users, maintainers and emergency responders) is tasked to design a tunnel life safety system, the designer will need to establish how the system is going to be operated and monitored – automatically, manually or (normally) somewhere in between the two. Quite early on within the detailed design process, the designer needs to understand the capabilities of the operator in order to be able to conduct the design.

SPECIFICATION

Before a designer can commence a design he needs a specification to work to. The first part of the specification process usually entails the client authority deciding what they actually want (often including being advised of what they ought to have). Section 1 of Annex I of the Road Tunnel Safety Regulations (RTSR, the UK enactment of the EU Tunnel Directive – and a verbatim copy from the Tunnel Directive Annexes) is titled Basis for Deciding on Safety Measures – the author can think of few better places to start.

Annex I section 1.1 states that "Safety measures to be implemented in a tunnel shall be based on a 'Systematic Consideration' of all aspects of the system composed of the infrastructure, operation, users and vehicles". It goes on to say:

"Where a tunnel has a special characteristic as regards the aforementioned parameters [sic the regulations include a list of items to consider], a risk analysis shall be carried out in accordance with Article 13 to establish whether additional safety measures and / or supplementary equipment is necessary to ensure a high level of tunnel safety. This risk analysis shall take into consideration possible accidents, which clearly affect the safety of road users in tunnels and which might occur during the operating stage and the nature and magnitude of their possible consequences". It then goes on to require:

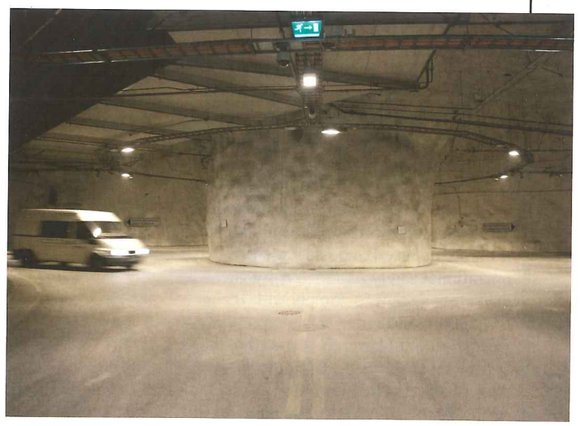
"The safety measures required by the following paragraphs [sic the regulations include several pages of detail requirements] shall be implemented at a minimum in order to ensure a minimum level of safety in all the tunnels."

The 'Systematic Consideration' process is designed to lead to an overall specification for tunnel life safety systems that should be included within the client's procurement specification. The procurement specification tells one what is requested (such as a ventilation system, a lighting system, wayfinding signs, fire main etc) and its operating requirements but it often doesn't tell you much about the actual systems themselves. That is the realm of the detailed designs eventually produced by the system designer.

Annex II of the RTSR is titled, "Approval of the Design, Safety Documentation, Commissioning of a Tunnel, Modifications and Periodic Exercises" and is also critically important for the Design process. At paragraph 2.2, Annex II requires that the "Safety Documentation for a tunnel that is at the design stage shall include a description of the planned structure and access to it, together with the plans necessary for understanding its design and anticipated operating arrangements".

FORESIGHT

An obvious question that arises from



Below: Illustrative photo of a road tunnel junction

the above is "how does a designer know what the anticipated operating arrangements for the tunnel are?" Clearly, these anticipated operating arrangements must be either developed and stated as a part of the Systematic Consideration or they're left to the designer to invent - which sounds very much like an open door to the much loved compensation events of NEC contracts. In reality, there has to be some sort of iterative process between the designer and the operator such that the final system is fit for purpose.

To return to the client's procurement specification; how do we ensure that the client's specification is implemented in the manner in which the client intended? Well, we could specify the use of Reliability Centred Design – now we're getting sophisticated - we're now objectively determining the required level of reliability and availability that our life safety systems must achieve.

We can get really enthusiastic, reach for the calculator (or better still, model it on a computer) and calculate the operational safety parameters for the life safety system to comply with BS EN61508 – and arrive at an appropriate Safety Integrity Level (SIL) that the final system must achieve. Regrettably, there doesn't appear to be too much sign of this in the UK. Much too often we

*Above: **Illustrative photo of a well lit road tunnel with clear exit signs***

end up with a client's functional specification that's littered with what a lawyer might describe as "innominate terms" – requirement 'wish lists' that have little if any measurable meaning.

There still remains a rather large 'fly in the ointment' – the operation and monitoring of the system - which takes us back to the role of the tunnel operator. The author firmly gets the impression that most designers of tunnel life safety systems do not have the faintest idea of what tunnel operators do, or what their capabilities are. Similarly, they do not seem to have much of an appreciation of the role of the Police or of the Fire & Rescue Services during a tunnel emergency incident.

The author does not blame them for either, very few designers get the chance to spend time with tunnel operators or with the emergency services) so how should they be expected to know?

By way of some background, both the Police, and the Fire & Rescue Services have to operate within the Health & Safety at Work Act. When attending an emergency incident, Volume 2 of the Fire Service Manual advises that:

- Fire fighters will take some risk to save saveable life
- Fire fighters will take little risk to save saveable property
- Firefighters will not take any risk at all to try to save lives or property that are already lost.

A key issue for designers is that the Fire and Rescue Services are not a panacea; they have to operate within risk assessed limitations (albeit limitations far in excess of those within which most of us have to contend). It is never safe to assume that "the Fire and Rescue Services will sort that out" because the chances are that they won't.

Tunnel operators have to operate within their own unique set of constraints. Historically, it was quite difficult for a

Table 1. Diploma in Road Tunnel Operations

Unit Reference Number	*Unit Title*
Y/504/6744	Introduction to Safety in Road Tunnel Environments
D/504/6745	Introduction to Road Tunnel Control Room Operational and Emergency Procedures
H/504/6746	Road Tunnel Structures and the Safety Function Provided by the Life Safety Engineering Systems
K/504/6747	Tunnel Systems and Equipment for the Safe Operation of Road Tunnels
M/504/6748	Operating Road Tunnel Life Safety Engineering Systems – Tunnel Ventilation
T/504/6752	Operating Road Tunnel Life Safety Engineering Systems – Facilities for the Road User and Evacuation Systems
A/504/ 6753	Operating Road Tunnel Life Safety Engineering Systems – Facilities for the Emergency Services
F/504/6754	Operating Road Tunnel Life Safety Engineering Systems – CCTV Systems
J/504/6755	Implement Road Tunnel Emergency Procedures
H/504/6763	Managing Fire, Flood, Chemical, Biological, Radiological, Nuclear or Explosive Events in Road Tunnels
Optional units	
T/504/6749	Operating Road Tunnel Life Safety Engineering Systems – Tunnel Drainage
M/504/6751	Operating Road Tunnel Life Safety Engineering Systems – Active Fire Suppression
L/504/6756	Liaise with the Media Regarding Operational Traffic Management
R/504/6757	Respond to and Provide Support at Incidents on the Road Network
Y/504/6758	Patrol Road Tunnels in Official Vehicles on the Road Network
D/504/6759	Escort Vehicles to a Place of Safety on the Road Network
R/504/6760	Remove Vehicles and Obstructions from the Road Network
Y/504/6761	Respond to Traffic Management Incidents – Bronze Command
D/504/6752	Preparing for the Coaching Role

Source: RTOA

designer to obtain a semblance of understanding of the role, processes and modus operandi of a tunnel operator. With the development of the Diploma in Road Tunnel Operations this situation should (hopefully) have become a lot clearer, and created a mechanism for the designer to integrate the Operator issues within his design process.

In order to place UK Tunnel Operations on a firmer footing, the Diploma in Road Tunnel Operations (DRTO) was formulated by the Road Tunnel Operator Association (RTOA); following extensive dialogue, the RTOA invited Proqual to become the Awarding Body for the qualification.

It is a vocational qualification that comprises the following units:

To obtain a Diploma it is necessary to complete all of the Mandatory units and two Optional Units. More units can be taken if that is considered necessary at a particular tunnel (e.g. Unit M/504/6751 – Active Fire Suppression). It is also possible to register fewer units and obtain a Certificate in Road Tunnel Operations – or indeed register for a single unit and obtain unit accreditation in that area. Whilst primarily intended as a qualification for Control Room Operators, the Diploma can also provide a excellent grounding in tunnel operations for other members of staff (say a newly appointed Tunnel Safety Officer, or Tunnel Manager).

Hopefully, the advantages to Designers of Tunnel Life Safety Systems in having this qualification available start to become readily apparent.

If a designer is designing a tunnel system, a part of their design is likely to require the system to be operated or monitored in a specified manner. Their system design can now require the tunnel operator's staff to be qualified and certified in the use of that system in the manner specified by the designer within the qualification certification provided by the DRTO.

Clearly, the tunnel operator could not tolerate having a cumbersome and complex operating regime foisted upon them, the exact input provided by the tunnel operator does, by necessity, have to be arrived at via a dialogue between the system designer and the tunnel operator. Ultimately, this is a process of risk apportionment between the designer and the tunnel operator; the tunnel operator may well be willing to accept and manage a risk provided that the designer provides him with the tools necessary to manage it. The Operator can then go and design (yes, design) his own operational procedures and processes, test them, subject them to review and offer them to the TAA (Technical Approval Authority) for authorisation, train the operational staff, test their competence and then fully implement them and the associated ongoing revalidation processes throughout the life of the system.

For designers of tunnel life safety systems, the Diploma in Road Tunnel Operations provides an opportunity to underpin those aspects of the monitoring and operation of their system that require human input with an Ofqual nationally approved and certified qualification and move us all a further step away from an encounter with those whose attire includes a curly wig

IMPROVED SAFETY MEASURES IN ROAD TUNNELS FOR PEOPLE WITH REDUCED MOBILITY

Ali Mahdmina
Ali is a manager of engineering processes an innovation and quality focus

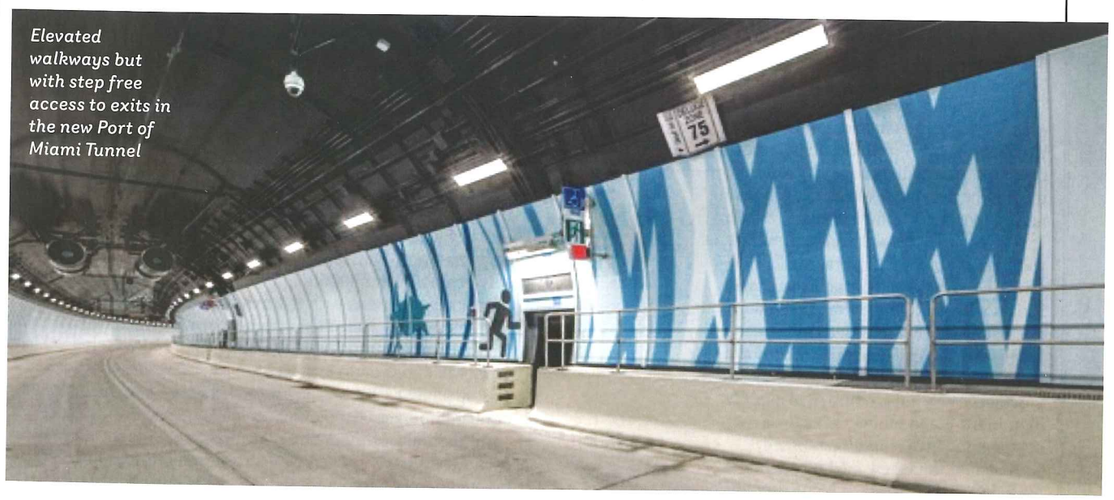
Peter Bishop
Peter is the tunnels technical director for Mouchel, based in Liverpool

Having previously examined (in the August issue of *Tunnels and Tunnelling International)* what constitutes a person with reduced mobility in terms of a road tunnel evacuation, outlined the legal position on provision, and highlighted the very real barriers disabled person's face in tunnels, *Mouchel's* **Peter Bishop** and *Imtech Traffic & Infra UK's* **Ali Mahdmina** now turn their atttention to the design, procedural and technological solutions that can improve and enhance the current position

IN THE last 10 years many new twin-bore tunnels constructed around the world have been provided with cross connecting doors at road level at intervals varying between 100-500m, which permit self-rescue escape for someone with reduced mobility using a wheelchair.

However, the new concept of double deck Duplex tunnels such as A86 around Paris, which was opened in 2009, have been built with interconnecting staircases between levels, along with periodic refuges, as part of their escape strategy. A new eight lane, double deck cut and cover tunnel through Maastricht in the Netherlands is likely to pose similar challenges for those with disabilities or reduced mobility.

With some 8,300 road tunnels of varying length, and a high proportion over 500m long, Japan can justifiably claim



Elevated walkways but with step free access to exits in the new Port of Miami Tunnel

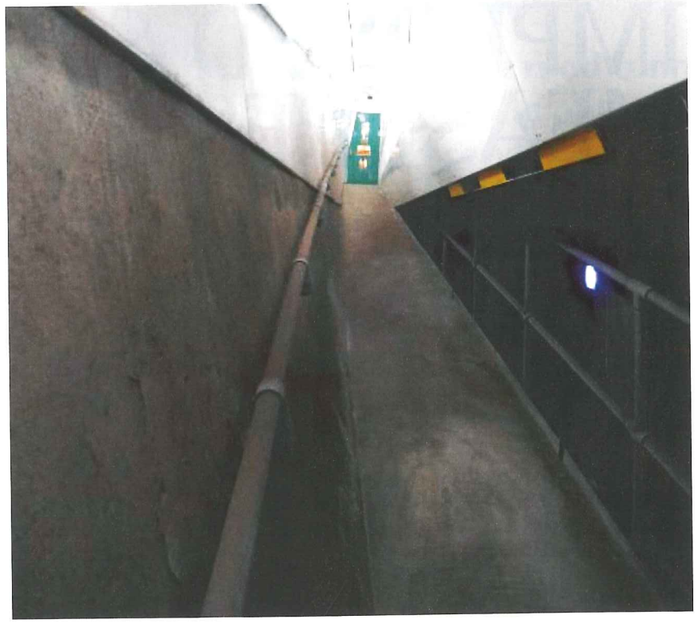
to be one of the leading Nations in terms safety provision with a specific criteria governing planning, design and operation, called the 'National Safety Standard of emergency facilities on Road Tunnels'. While many of the older stock operated by Nexco Expressway Company feature elevated walkways of varying heights, the more modern twin tube tunnels have been constructed with spacious cross connection doors at road level at a maximum of 350m intervals.

Elevated concrete walkways, with handrails, are also extremely prevalent in tunnels across the USA. The 'Americans with Disabilities Act' (ADA) titles relating to 'Public Transportation' and 'Public Accommodations' along with the 1968 'Architectural Barriers Act' (ABA) have not yet been amended to consider the safety provision for persons with reduced mobility, with no reference within the applicable NFPA Design Standards 502 or 101 (chapter 7) to meet the needs of either elderly or disabled during evacuation.

In the United States there appears to be an assumption everyone has the ability to climb steps in an emergency and that when necessary the physically strong will assist those less able. That said, recently opened tunnels such as the fourth bore of the Caldecott in California, and Port of Miami, have gone some way to being accessible from road level, despite the inclusion of elevated walkways, but the design of Highway 99 Seattle 'big dig' tunnel has followed the Paris model with a Duplex double road deck connected by stairs to a central evacuation gallery. When completed, disabled persons will have to wait in a shelter until rescued by fire fighters.

The situation in Australia is not dissimilar, with no specific reference in individual State Tunnel Design codes. A number of the current tunnels have elevated walkways which necessitate climbing stairs to access emergency exits, however exits in the new Legacy Way Tunnel in Brisbane are step free but culminate in a sliding door which may require the assistance of an able bodied person to open.

The position around Europe is mixed, with a good proportion of accessible exits to be found in Austria, Switzerland, Spain, Netherlands, and France to name but a few with the later setting the 'safety' bar extremely high, in terms of technological features and operational processes, within the refurbished 11.6km long Mont Blanc tunnel. Nevertheless, connection between the pressurised shelters and the invert final escape route is still via staircases. Norway



Above: One of the 1:8 ramps to a Mersey Queensway refuge

meanwhile, has 1,100 road tunnels including the Laerdal, the World's longest at 24km, and specifies differing levels of safety equipment provision depending upon the tunnel length and traffic volume.

As far as can be ascertained only Germany has acted to amend its 'Federal Highways Act' (FStrG) and 'Guidelines for Furnishing and Operating Tunnels' (RABT) in light of the UN Charter, the EU Directive, and the German Federal Act on Equal Opportunities for the disabled.

While the United Kingdom is in the process of updating its Tunnel design code BD78/99 to reflect the contents, and impact, of the Regulatory Reform (Fire Safety) Order 2005, the Road Tunnel Safety Regulations 2007, and the Equality Act 2010, new tunnels such as Hindhead and Tyne Tunnel 2 were designed with universal accessibility in mind while the original Tyne Tunnel was transformed internally with the creation of an accessible fire proof escape corridor over its full length.

Operators of existing Highway England and Welsh Government tunnels have also made 'reasonable adjustments' wherever possible. There are several older tunnels however, such as Blackwall and Rotherhithe in London, where the physical and operational constraints have so far restricted any noteworthy adaptation.

ABOVE AND BEYOND

But one UK Tunnel Owner/operator, Merseytravel, has gone well beyond 'reasonable adjustments' and in the process of upgrading 'Kingsway' and 'Queensway' Mersey tunnels between 2002 and 2006, set a benchmark in the escape provision for persons with reduced mobility.

There are two tolled road tunnels beneath the River Mersey. The older of the two is called 'Queensway' and was opened in 1934 while a second twin bore tunnel, known as 'Kingsway' was opened in 1971 and between them they have a combined annual throughput of around 26 million vehicles.

In the wake of the 1999 Mont Blanc and Tauern tunnel fires, Merseytravel reacted by first reviewing its existing evacuation provision in the Kingsway Wallasey Tunnel

(via elevated walkways) and then in 2002 authorising the construction of three additional 17m long cross passages - spaced at around 300m apart - between the two tubes. A key component of the design and delivery was that the new permanently illuminated escape passages should be at road level, and step-free, to make them fully accessible to persons of reduced mobility.

Three years later Merseytravel embarked upon a further multi million pound investment to upgrade the escape provision in the Queensway Birkenhead Mersey Tunnel with particular reference to the requirements of disabled and others with reduced mobility.

Following a study of all the options plus a series of trials by the design team, the concept adopted was to cut through the side-walk, and road deck, at approximately 200m intervals, prop the deck structurally, and then construct ramps, rather than stairs, within a stainless steel fire protected entrance, with integral crash barrier. Thus, refuges and ramps were contained within the 44ft (13.4m) diameter envelope, avoiding further excavation through the tunnel lining.

These ramps would lead escapees, via a series of two-hour rated fire protected doors, to seven refuge chambers (all linked to a connecting escape route) situated in the airway invert beneath the road deck, and there they would stay until the incident was deemed over by emergency services. A further stage of the design process focused upon the spatial requirements within escape passages for ambulant and non ambulant evacuees, those in wheelchairs, and even fire-fighters carrying a stretcher, with particular emphasis on the required envelope and the gradients of the ramps.

The design of the ramps was based upon downward gradients of 1:12 and 1:20, with landings, complying with UK Building Regulations part M, however to prove the design, and reduce the length of travel to 'reasonable' proportions, ramps were designed to oppose the tunnel gradient and a full scale prototype of a shelter entrance with a variable gradient ramp was constructed off site, tested and approved by disabled groups and RADAR members. In the end it was found that a 1:8 ramp was acceptable in this instance.

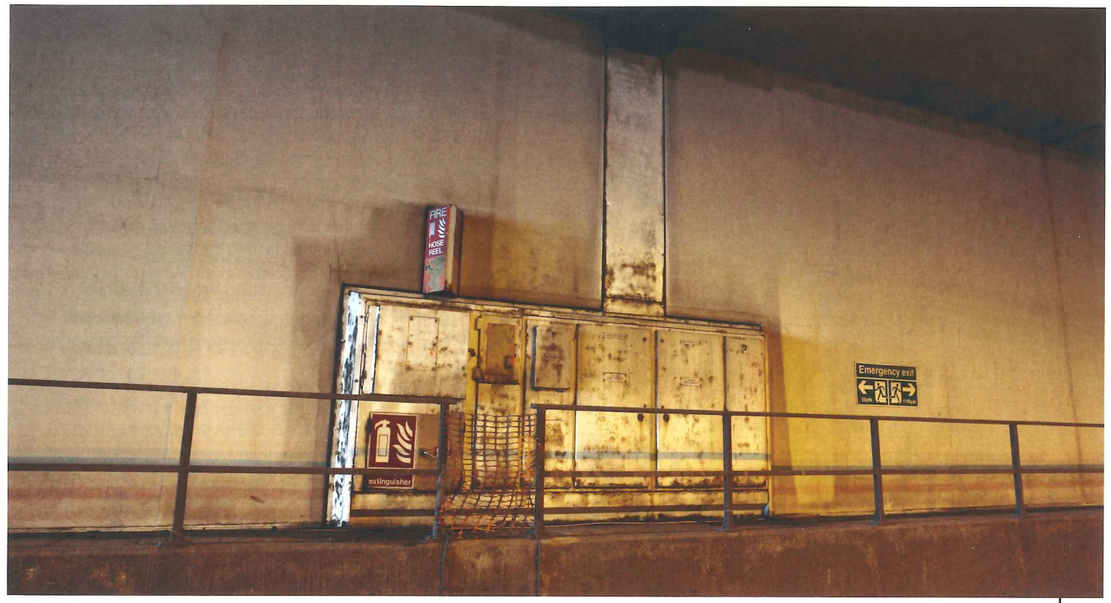
When Queensway Tunnel safety upgrade was completed in 2006 the following facilities had been introduced with the specific intention of meeting the needs of persons with reduced mobility in the event of an emergency evacuation.

- Step-free access via non slip ramps to seven pressurised safety refuge chambers beneath the road deck.
- All two-hour fire rated doors fitted with vision panels and push bar opening.
- Emergency SOS telephones in niches adjacent to refuge entrances positioned at a height accessible to someone in a wheelchair. CCTV coverage for entrances, ramps and refuges all linked to the Tunnel control room.
- Extra-large green photo luminescent 'man running' signage to British and European standards indicating the entrance to a fire door.
- An 'active' high-visibility evacuation system - triggered by Tunnel controllers – featuring an initial radio break-in message followed by a zonal PA instruction, green illuminated chaser arrows pointing towards the exit door, low level way finding signs indicating the distance to the nearest exit, high intensity strobe lighting around the door lobby plus a white noise directional sound beacon with 'Exit Here' voice-box for the benefit of those with impaired eyesight or persons in difficulty due to reduced visibility in the tunnel.
- Each 180-person capacity refuge chamber provided with an accessible disabled chemical toilet, some seating, and a supply of fresh drinking water together with first aid equipment, orientation and instructional signs, and two-way audiovisual communication with a dedicated and specially trained handler in the tunnel control room.
- Alongside each fire exit from the tunnel road deck, a lightweight, folding wheelchair was positioned within a touch button, easy access, enclosure for emergency use by those unable to access their own wheelchair or to facilitate transportation by a helper of a person whose mobility is compromised.
- Enhanced lighting levels both in the main tunnel itself and on escape routes once an emergency evacuation is in process.
- At the two points, some 1,500m apart, where the invert escape route walkway terminates at a staircase shaft to the surface, a standard ambulance sitting stretcher with wheels has been provided in an easy access enclosure for the use by emergency services only to transport a non-ambulant person up stairs to the surface.
- Standard operating procedures were re-drafted to ensure rescue priority is given to assisting, any persons in difficulty due to reduced mobility including the elderly and young families.

POSSIBLE TECHNOLOGICAL ENHANCEMENTS

Given that there is no universal means to externally identify a vehicle carrying a disabled person (such as a plate on the rear) the authors would wish to explore the possibility of adapting the current flashing 'hazard light' system incorporated in all cars, so that in a vehicle used by, or registered to, a disabled person they are adapted to flash at a recognisably different intensity and frequency signalling the classic 'S.O.S' message. This would indicate to others the occupant is in distress, or importantly in a tunnel situation, trapped in their vehicle. The authors recognise the difficulty in achieving consents for this, but would argue this simple adaption to hazard flashers on vehicles carrying disabled persons would be universally recognised by rescue crews and many other drivers, both on the open road and in tunnels.

The means of detecting the presence in the tunnel of a person or persons with an impairment to mobility stranded in



their vehicle have been explored, and the following is proposed.

- By utilising Automatic Number Plate Recognition (ANPR) upon entry and exit, tunnel operators will be able to identify specific vehicles registered to disabled drivers and potentially track their passage through the tunnel on CCTV.
- In the UK, all vehicles adapted for, or registered to a higher level of disabled person are exempt from road tax, and are therefore identified as 'special needs' within the registration hierarchy. Thus, in the event of an incident, a tunnel operator, with appropriate levels of permission, would be able to connect to the DVLA (or equivalent vehicle registration organisation outside the UK) database for vehicles registered to disabled persons and cross check it in seconds against known vehicles stopped inside the tunnel. It is suggested this system is called 'Mobility Impaired Recognition System' (MIRS).
- This would enable the tunnel controller to identify any vehicles where the occupants may have mobility difficulties in evacuating their vehicles, and then alert emergency services or tunnel rescue teams.
- A very notable exception from the DVLA database though are persons with hearing impairment, who might well be at a disadvantage compared to persons with physical disabilities. Currently in the UK vehicles used by persons with reduced or total loss of hearing do not qualify for tax exemption – as they are not adapted – so Operators would not be aware of the presence of persons suffering this type of disablement.
- This is particularly relevant given most evacuations are initiated by radio break-in messages, instructions via public address systems, and directional sound beacons over exit doors, thus highlighting the need for visual and active signage.
- The 'MIRS' facility referred to above could be utilised both in the event of an incident where a single vehicle has broken down in the tunnel or multiple vehicles have stopped due to a Road Traffic collision, a vehicle on fire or similar emergency. The detection of stopped traffic and a related incident is carried out by means of video, radar, thermal imaging or audio listening systems, collectively referred to as AID (Automatic Incident Detection), however, the authors consider MIRS would operate independently to AID systems.

Above: Difficult and obstructed access to an elevated walkway

The likelihood of a person left behind in their vehicle once evacuation has commenced is particularly applicable for those whose mobility is reduced by a disability, but certainly not exclusive. Paralysis induced by fear can incapacitate some drivers and passengers so detection of those vehicles where there is no immediate pedestrian movement during evacuation is paramount for the occupant's safety.

A methodology and means to enhance AID systems responses is explored as follows.

- During an incident when multiple vehicles are stopped within a tunnel it is normal practice for the AID system to inhibit further alarms so the tunnel controller is not expected to acknowledge multiple warnings of a stopped vehicle, as he will be aware after the first incident alarm. If an instruction to evacuate is given by all available technological means, there is likely to be a period of extensive pedestrian movement, which again will normally trigger alarms.
- While the proposed MIRS system is one means of highlighting to controllers the presence of a

vehicle carrying a disabled person, a second option is available as it is also technically feasible to create a new base line for the AID system, specifically for the background data, initiated by a simple button click, once a queue of standing traffic has formed. The queue of vehicles would then become part of the background data and anything extra to this, such as pedestrians, will become easier to identify.

- Conversely, where there is no pedestrian movement from a standing vehicle, i.e. the doors have not opened and the occupants have not extricated themselves inside an agreed timeframe, this would be highlighted by the AID system as an 'alarm' behaviour, at which point the controller could address the occupants via the PA system, and in the event of no apparent response, direct rescue crews towards the vehicle.
- The authors have consulted a major worldwide manufacturer and installer of automatic incident detection systems and received a positive response with a new background level to cover queuing traffic and alarm status for non-movement around a vehicle considered technically feasible with some extra cost to develop. Such an enhancement would add significant value to the use of such systems.

POSSIBLE ENHANCEMENTS

If fixed or variable message signs exist on the adjacent highway network approach to a tunnel, they should display a picture indicating drivers should leave a minimum distance of 3m when stopped behind another vehicle during a traffic stoppage or congestion. This will allow sufficient clearance to operate a wheelchair lift. In addition, operators could better utilise available tunnel safety systems such as in-tunnel variable message signs and radio re-broadcast to interrupt with brief safety messages – targeted at anyone with reduced mobility.

In the UK all new 'Motability' adapted vehicles for disabled are automatically fitted with tracking devices – ostensibly to prevent fraudulent use, but regular users of a route which includes passage through a tunnel could, theoretically, be targeted with evacuation/emergency instructions and operators alerted of their registration number.

Additionally, all 'Motability' scheme vehicles are registered with the DVLA as some used by persons with higher levels of disablement are exempt from payment. With increasing use of ANPR for congestion charging, road, tunnel and bridge tolls, a vehicle registered with the DVLA (or similar registration plate issuing organisation) as being owned, or used exclusively, by a disabled person, can be almost instantaneously identified via its number plate, enabling a Network or Tunnel operator to receive a warning alert before, or just after, it enters a tunnel. In the event of an incident and evacuation, the alert will be logged and operators can notify on-road staff to target the vehicle for special help.

A folding aluminium standard wheelchair can cost as little as GBP 160 (USD 240), yet is a potential lifesaver to anyone trying to assist someone who are either unable to access their own wheelchair or is compromised by their inability to walk the distance to a place of safety unaided. Emergency wheelchairs should, therefore, be provided in suitable easy access enclosures at periodic positions along the length of a tunnel possibly as part of each emergency point/ SOS telephone niche.

Improved education for drivers on how to behave in a tunnel emergency is another important factor to consider. If there is a toll plaza, operators should give out an instruction leaflet with tickets, promote the tunnel evacuation strategy on corporate and News web-sites, and seek to use all media outlets to publicise how both able bodied, and disabled, should respond to an evacuation instruction. Such messages must underline that staying in a car is not an option. Understanding the significance of adapted hazard warning lights as proposed in this article would also form part of the UK Highway Code, theoretic driving test and international equivalents.

If the staircase to a refuge, or escape gallery, is of relatively short assent and of sufficient width to permit escape by three persons side by side, consider the installation of a wheelchair lift, or inclined platform lift, to one side. If it is not possible to dispense with stairs altogether in favour of accessible ramps, the shaft design of tunnel escape staircases should at least cater for the installation of an evacuation/fire-fighting platform lift capable of carrying a wheelchair up to 400kg over seven metres of travel.

Many tunnels already have public address systems enabling controllers to convey a series of standard pre-recorded messages to stopped traffic in an emergency, the content dependent upon the situation in that particular zone. A further series of focused, more reassuring messages, should be developed to address any vehicle(s) where CCTV or AID has identified the occupants have declined to, or are struggling to, evacuate their vehicle within set timescales.

Even allowing for the interpretation of what constitutes reasonable adjustments to existing infrastructure, it is clear from our research there needs to be a sea change in attitude by tunnel designers, operators, highway owners, and in some cases, governments, to ensure the rights of disabled persons, and the wider group of those whose mobility may be compromised during an emergency, are protected to deliver the 'Universal accessibility' all nations committed to in the 2006 UN Charter.

It is the authors' hope this article, and their presentation of a paper on the same subject at the World Road Congress in November 2015, will challenge thinking in some parts of the world and hasten change which will one day save the lives of those less able during a tunnel emergency

Reference

Please also read Peter Bishop's article from Tunnels and Tunnelling International, August 2015, where he sets out the problems to which this article présents solutions.

UNDERGROUND UTILITIES

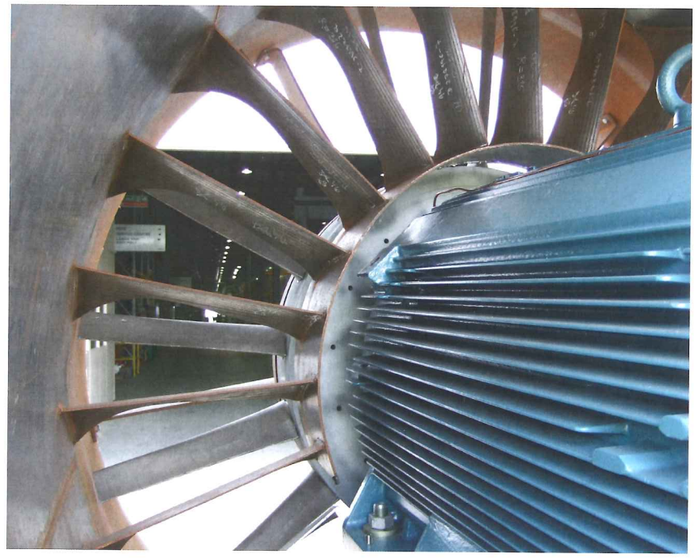
WEBSITE LAUNCHED

Underground Utilities has launched a dedicated website that covers the entire underground construction market from trenchless technologies to innovative pipe repair methods and modern trenching equipment. As sister website to Tunnels and Tunnelling International, Underground Utilities serves the small bore industry

www.uu-magazine.com

IS TUNNEL VENTILATION SUSTAINABLE?

Tunnel ventilation can consume substantial power, which can amount to several megawatts, as well as requiring expensive structural space and electrical facilities. Although sustainability is now recognised to be a key goal for infrastructure development, its application to tunnel ventilation is still in its infancy. This article by **Fathi Tarada**, secretary of the World Road Association *PIARC*, and MD of *Mosen* summarises some key lessons from the forthcoming *PIARC* report on sustainable road operations, and draws some examples from practice



Above: A large Flakt Woods axial fan during certification tests

THERE IS increasing interest in the application of sustainability concepts to tunnel ventilation design, installation and operation. This is due to the need to reduce energy consumption as a means of minimising carbon footprint, the commercial imperative to reduce costs at all stages of the infrastructure life cycle, and the requirement to enhance equipment availability.

The World Road Association (PIARC) is about to publish a report on "Recommendations for Sustainable Road Tunnel Operation", which contains a survey of existing frameworks for sustainability, including various national regulations and guidelines. The report also includes chapters on identifying and reducing costs associated with tunnel civil works and equipment. This paper includes a summary of some aspects of the PIARC report in the areas pertinent to tunnel ventilation.

SUSTAINABILITY CONCEPTS

The Brundtland Report (1987) and the 1992 Rio Summit have set a general framework for the concept of sustainability. According to the Brundtland Report, sustainable development is the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The sustainable development concept is based on three main pillars:

- Social: meeting needs in terms of health, education, housing, employment, etc.;
- Economic: creating wealth and improving living standards;
- Environmental: preserving species, natural resources and energy resources.

The end-goal of a sustainable development approach is to find a balance between the three pillars and preserve this balance over the long term.

Contrary to certain common beliefs, the concept of sustainable development does not solely rest on the objective of preserving the environment. It also aims to meet social needs and economic requirements. It is thus generally represented by three pillars, which should roughly have the same weight (see Figure 1, page 42).

Fathi Tarada
Fathi is managing director of Mosen and secretary of PIARC

Sustainable development represents a holistic approach of the whole life cycle of a project, and requires a balance to be struck between economic, social and environmental objectives. A sustainable design must recognise the integrated nature of human activities and must therefore include a commitment to coordinate planning and design amongst all relevant sectors, disciplines and groups.

IS TUNNEL VENTILATION REQUIRED?

The first issue to be addressed is whether tunnel ventilation is required at all. Short tunnels, defined by the EU Directive on Road Tunnel Safety [1] as being 500m or less in length, or tunnels less than 300m in length in accordance with NFPA 502 (road tunnels) and NFPA 130 (rail tunnels), do not generally require any tunnel ventilation. Ventilation for such short tunnels is provided by natural air movements and by the piston effect of moving traffic. In case of fire, natural buoyancy and wind effects can push smoke towards one portal, possibly leaving the other portal clear for tunnel users to evacuate from.

For longer tunnels that do require mechanical ventilation, a number of variables including the tunnel length, vertical gradient, traffic flow, vehicle mix and the number of lanes can significantly influence the required ventilation capacity during normal operations. Due to the piston effect, many road tunnels less than 3km in length do not require any mechanical ventilation to preserve in-tunnel air quality during normal operations - with the possible exception of rush-hour traffic. Such an approach has recently been used to significantly reduce the energy consumption within the Mersey Kingsway and Queensway Tunnels, for example. Reducing energy consumption is good for the environment in terms of reduced emissions; saving financial resources may mean that public funds can be released to other social ends.

For many tunnels today, the determining design criterion for mechanical ventilation is smoke control in case of fire, rather than maintaining adequate in-tunnel air quality. Tunnels can therefore be equipped with significant ventilation equipment "in reserve", which is not normally used to full capacity. The reason for the installation of such equipment is for life safety, as evidenced by compliance to codes or by means of a risk assessment. Nevertheless, certain methods are available of reducing the power consumption of such an 'over-sized' ventilation system during normal operations: for example by switching all available fans on at lower speeds, and by including "redundant" fans in the normal operating cycle.

EXTERNAL AIR QUALITY

Tunnels do not create any emissions – rather, they contain and redirect emissions to outlet portals and ventilation stacks. However, the discharge of vitiated air can impact on the health of residents living close to the exit portals. In order to mitigate this effect, polluted air can be extracted up through exhaust stacks and dispersed, achieving 'zero portal emissions' – but this comes at a very significant cost in terms of civil, mechanical/electrical equipment and ongoing power consumption.

The Australian experience is very pertinent in assessing the sustainability of zero portal emissions.

Commencing with the M5 East Tunnel in Sydney (which opened in 2001), a restriction was applied to protect residents living in the vicinity of the tunnel portals, by arranging the ventilation system to achieve zero portal emissions. This restriction was later retained for the Cross City Tunnel (2005) and Lane Cove tunnel (2007). Zero portal emissions have subsequently become the de-facto standard for road tunnels in Australia.

To achieve zero portal emissions, all of the tunnel air must be expelled from the ventilation stack, with air being drawn in from all portals. This requires pulling air against the piston effect of traffic at the exit portal. Such an effect can only be achieved by increasing the volumetric flow rate of the air discharging through the stack, and increasing the stack's cross-sectional area.

Table 1, opposite, provides a summary of the power consumption figures for four Australian tunnels. The M5 East ventilation system energy use is equivalent to that of nearly 7,400 households; it is open to question whether such a ventilation system can be considered sustainable from an environmental perspective.

Nevertheless, any sustainable ventilation system must win the confidence of the community in the management of air quality within tunnels, as well as preserving local ambient air quality. A number of trials involving switching off the portal extract systems for the CityLink and Lane Cove Tunnels overnight and during low traffic conditions have been undertaken, with little impact on the ambient air quality levels being reported [2].

TUNNEL LIFE CYCLE

The operation of a road tunnel is highly dependent on the design and construction phases, which preceded the commissioning of the work. More precisely, it is necessary to take account of the effect of solutions opted for during a project's design phase on operating conditions. If the selected design solution is not ideal, it will be very difficult to improve the tunnel's sustainability throughout its life cycle.

PIARC has provided an estimate of the impact of the various phases of a tunnel project on operating costs. The data is presented in Table 2, and highlights the importance of good design to minimise operating costs.

The planning phase (study/design) is normally three to 10 years, the building/construction phase two to three years while the operation phase may be from five to 20 years for installations/equipment and 80 to 100 years for the tunnel structure. This does not account for possible refurbishment work undertaken on the tunnel.

Below: ***The Three Pillars of Sustainability***

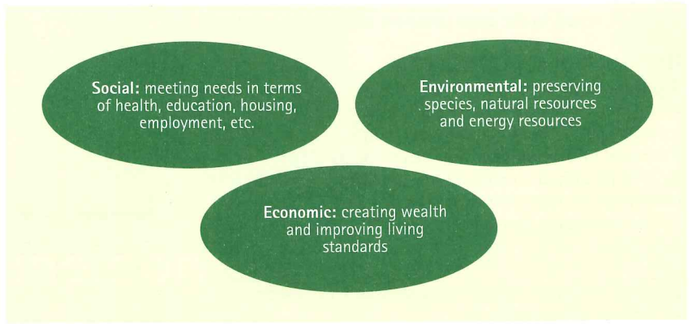


Table 1. Electricity Consumption for four Australian Tunnels

Project phase	Electricity consumption (MWh/annum)	Total (two way) tunnel length (km)	Traffic (vehicles per day)	MWh/km per annum
Eastern Distributor Tunnel	4,400	3.2	110,000	1,375
Lane Cove Tunnel	15,400	7.2	70,000	2,139
CityLink Tunnel (Melbourne	21,500	5	100,000	4,300
M5 East Tunnel	54,000	8	100,000	6,750

Source: Author

Table 2. Impact of project phases on operating costs

Project phase	Estimated impact
Design / study	60 – 80 per cent
Build / construction	10 – 30 per cent
Operate / tunnel lifespan	10 – 30 per cent

Source: Author

LOW-SPEED FANS

As an alternative to the installation of conventional axial fans in conjunction with attenuators to control noise levels, one option that may be considered is the installation of low-speed, large diameter fans.

Such fans typically run at speeds less than 200 rpm, and their impellers are produced from GRP material. The low-speed fans emit less noise than conventional axial fans, reducing or eliminating the need for attenuators and reducing the power consumption.

An overall saving in power consumption of 75 per cent may be possible with low-speed fans, compared to conventional axial fans.

However, these fans generate less static pressure than conventional axial fans. This makes the selection of the low-speed fans more difficult, since these fans are more susceptible to variations in pressure generated by traffic movement and wind effects.

Low-speed fans have been installed in a small number of tunnels, including the Spier Tunnel in Switzerland. However, the low-speed fans in the Spier Tunnel are almost never used, and thus there is almost no operational experience reported from them.

TECHNICAL INNOVATION

The forthcoming PIARC report outlines a number of technical innovations that can improve the sustainability of tunnels in general, and tunnel ventilation in particular. One of these innovations is the MoJet, which is a type of jet fan that features shaped nozzles.

The shaped nozzles reduce the Coanda effect, which is the tendency of the air steam produced by each jet fan to be drawn to nearby walls, leading to increased friction and significantly increasing the energy required to move the air.

This effect occurs because the jet flow close to the wall decelerates, creating a pressure difference across the jet that reinforces its attachment to the wall, even at high velocities. The reduction of the Coanda effect was confirmed by the use of 3D CFD calculations.

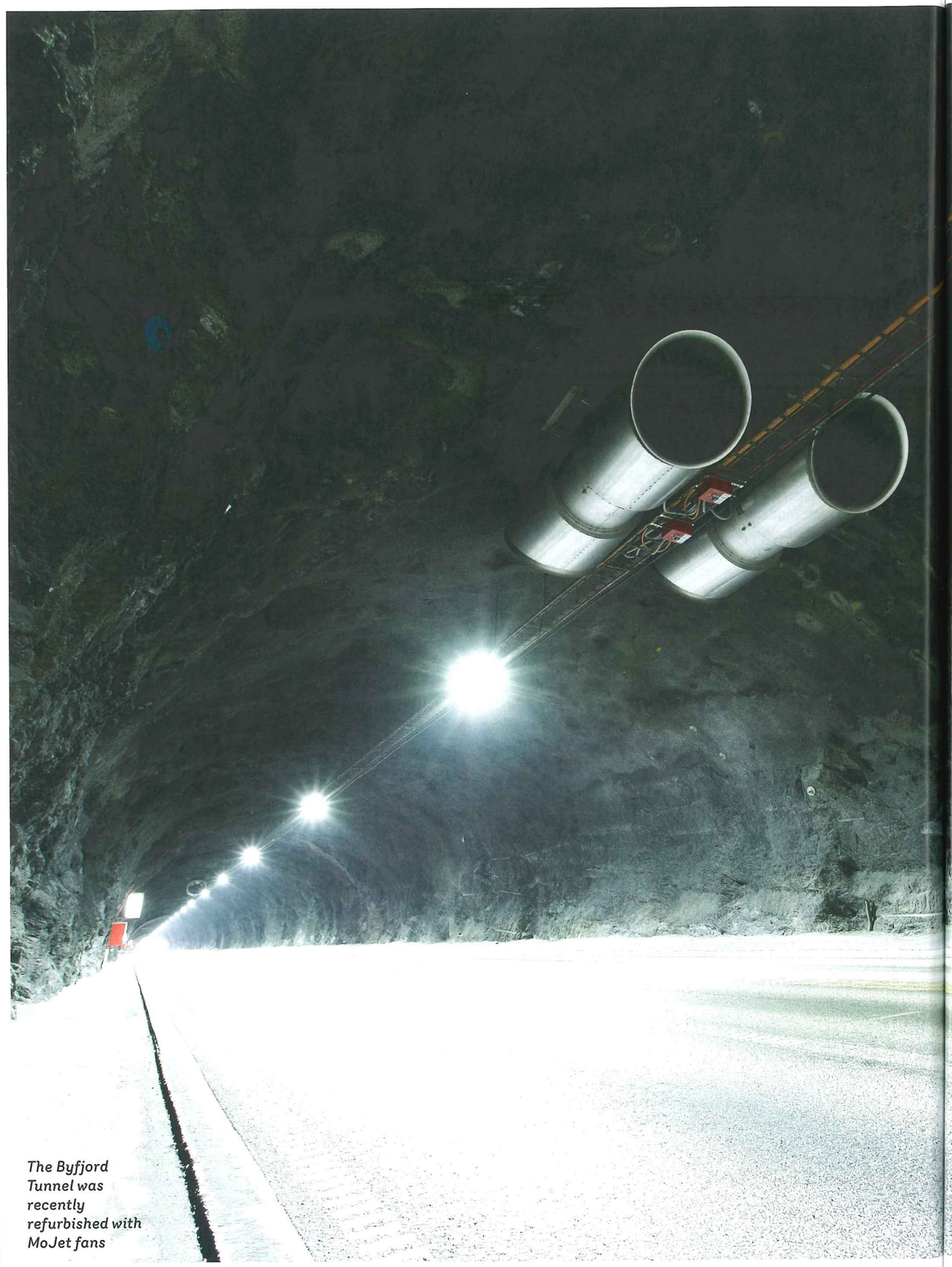
As an example project, an approximately 0.6km long dual tube road tunnel at a major international airport required significant refurbishment. The original specifications for the refurbishment called for 710 mm internal diameter conventional jet fans with two-pole motors. It was anticipated that this installation would be noisy, take up a lot of space, and possibly require increased safety precautions due to high jet velocities required for effective operation.

Four-pole motors were selected that run at half the speed of equivalent two-pole motors were selected for the design. The result was a 30 per cent reduction in power consumption and a 7dB reduction in sound pressure level in the tunnel, along with significantly reduced jet air velocity. In addition, the innovative jet fans could be installed much closer to tunnel walls and at reduced distances along the tunnel, reducing construction and cabling costs.

UNNECESSARY INSTALLATIONS

There is a significant amount of evidence that some aspects of tunnel ventilation installations are unnecessary, and hence do not represent sustainable infrastructure. A good example of this relates to tunnel air filtration systems.

For example, the filtration plant for NOx and particles within the Opera



The Byfjord Tunnel was recently refurbished with MoJet fans

tunnel in Oslo, Norway is no longer on operation due to its excessive energy consumption, large maintenance and operation costs and its low efficiency. The same decision has been also made for six other tunnels in Norway, which were equipped with more recent generation of filtration technology.

In the case of M30 tunnels in Madrid, the filtration system is automatically switched on when the corresponding exhaust fans are in operation. However, these operate very rarely due to a limited level of pollution, which is largely lower than the one expected during the design phase.

Air filtration is successfully used in a number of tunnels in Japan. For example, the air cleaning equipment has been installed and is still operational at the Chiyoda and Yamate tunnels in Tokyo, Japan.

FUTURE SUSTAINABILITY

A robust approach to achieving sustainability requires the simultaneous consideration of the social, economic and environmental impacts of any design and operation proposals throughout a tunnel's life cycle. Statutory requirements, technical guidelines and frameworks should all be considered in formulating holistic strategies for the design and operation of tunnels.

The application of such holistic considerations is very challenging, but progress can nevertheless be made through focusing on certain aspects of sustainability, such as reducing operating costs, eliminating unnecessary installations and ensuring social acceptability.

Tunnel ventilation provides a significant opportunity for sustainability improvements, particularly for long tunnels, which can absorb significant amounts of power.

Although the initial design of a tunnel has the greatest impact on a tunnel's subsequent sustainability, it is still possible to achieve significant improvements based on improved operations and through the subsequent installation of innovative technology

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[1] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV:l24146
[2] http://www.transurban.com/sr11/interactive/files/images/pages/page17.swf
[3] NSW Government's "Initial Report on Tunnel Air Quality", July 2014

www.tunnelsonline.info

TBMS RETURN TO NORWAY

For the first time in three decades Norway is using a TBM for one of its long tunnel projects, the Ulriken near Bergen. The drive is just beginning reports **Adrian Greeman**

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

NORWAY'S OSLO to Bergen railway, climbing 1,237m over the country's north-south mountain spine, is usually listed as the 'second most scenic' in the world. Presumably the Canadian Rocky Mountains take the top spot.

Either way much of the passenger load along its 492km single track is from tourists both summer and in the winter skiing season, though it is also important for freight. But near to Bergen the main demand is from commuters into the coastal city, second largest to the capital and a major oil industry centre. Some 120 trains use the line daily.

It means the line is at full capacity and particularly through a 7.7km-long single bore tunnel just outside the city, the main bottleneck on the route. It passes underneath the Ulriken Mountain and was opened in 1965.

Below: TBM being moved towards the portal

DOUBLE UP

Work is in hand now by the Norwegian National Rail Administration, Jernbaneverket, to double the track from the town of Arna into the centre, with the key part of the project being a second parallel bore to the first tunnel. Just 30m away from the first bore it will be slightly longer at 7.8km and linked to the first by both rail track cross over connections at one end, and 16 cross passages for safety and maintenance.

"Nine of those will also house mechanical and electrical equipment," says the Administration's head project manager for the scheme, Hans-Egil Larsen.

It would be typical in Norway for a tunnel like this to be built using drill and blast. The technique suits the very hard rock typical of the Baltic Shield geology and the country has significant contracting experience in the method. The Ulriken Mountain is not out of the ordinary or in a soft ground area; in fact its rock is some of the hardest in the country says Larsen, a granite that is competent and unfractured. "It is at the high end of the hardness scale," he says.

But in fact the work will primarily be done by TBM, in this case a hard rock open type gripper machine from Herrenknecht, driving a 9.33m outer diameter tunnel. It will be the first rail tunnel using a TBM in Norway, and one of the first TBM drives made in the last 30 years.

CHOICE OF EXCAVATION METHOD

A primary reason for choosing the machine, apart from general advances in TBM technology, is that the new Norconsult designed tunnel lies close to the old one, just 30m away. Drill and blast methods would need to pay attention to the proximity of the original tunnel and the trains, which will continue to run throughout the project.

In fact nearly a dozen companies bidding on the project were given the option to use either TBM or drill and blast methods. But the best bid price, from a joint venture of Skanska's Norwegian arm and the Austrian firm Strabag, proposed the TBM method.

"The difficulty otherwise is that there are only a few windows in each day when blasting is allowed," explains project manager Torbjørn Tveit Bakketun from the Skanska side of the JV. Vibration risks in the live tunnel rule out blasting as trains pass and they only stop for four 35-minute periods.

Some blasting is needed however. The first 764m of the tunnel, as it leaves a new station being built at Arna involves a track layout that funnels several station platform lines into the two for the tunnel.

This section of the tunnel also includes track switches and obliquely running crossovers.

"The cross section varies from 60m² for single track to as much as 300m² where there are twin tracks with a third tracks diverging," says Larsen.

"And of course there are connections for safety tunnels between the new bore and the old one to be made," he says. At some points the caverns needed are 28m across.

The D&B work was the first task for the joint venture when it mobilised and came on site last summer at the Arna end of the project.

"Actually it had been intended to start on the Bergen side but we talked it over with the client in an initial stage and it made more sense to site the operations at Arna," says Bakketun. The Bergen side has a greater density of houses and other buildings almost up to the portal and Arna less.

There are environmental issues to pay attention to. A nearby stream is a particularly favoured wild salmon fishing spot and the contractor has had to channel and culvert this underneath the station early on, as well as ensuring operations properly clean any water discharge from the site or the tunnel itself.

"We have quite a high-tech processing plant for the water," says Bakketun.

Work forming the portal area began in August last year with tunnelling underway in November using two Atlas Copco three boom jumbo rigs to drill first of all a short side access adit and then the main bore in two directions, with the changing profiles needed for the blasting.

"We had one XF3 and one WE3 and the work has gone quite well," says Bakketun.

"We used Volvo articulated trucks to move the spoil, loaded with 350 wheel loaders with a side-tipping bucket."

The spoil, some 135,000m³ from this section was placed nearby in a temporary store and then loaded onto road trucks for a 7km haul to a local quarry where it was crushed for sale. The hard material is useful for multiple proposes.

At the end of the drill and blast section the tunnel splits, one half for the second of the two diagonal train crossing points and the other a 30m stub tunnel in which the TBM drive will begin. Assembly is currently underway outside the tunnel.

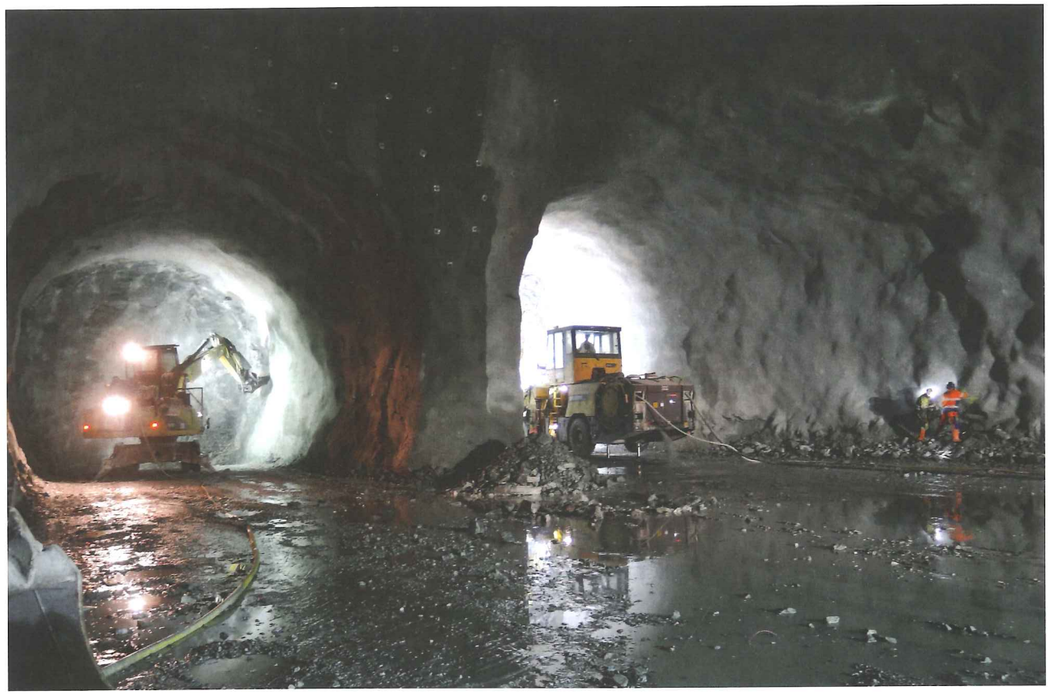
CRITICAL PATH

One advantage of beginning with this work was that it allowed time for the TBM to be ordered and delivered, says Bakketun. The machine, which is partly new and partly reconditioned, was factory ready in May and then delivered by ship over the summer, with a final move by truck from Bergen.

"Some 90 loads were needed" he says, "including some large special loads at night." One of the biggest was the 151t central section of the cutter wheel.

But an unusual assembly is being used for the machine. "Because we changed the start end of the tunnel from Bergen the original plan to put it together in a starting chamber was not

Below: TBM plus leapfrogging frame



possible," explains Bakketun.

Continuing drill and blast operations mean the machine must be assembled outside the tunnel. "We have prepared a small 50m long concrete pad just outside the main portal in a space close the Arna station area," says Bakketun. This is out of the way of the current operations which access the tunnel through the small adit to one side, and also clear of the existing tunnel and the continuing train operations.

Once it is ready the machine is moved forwards with a special 'leapfrogging' mechanism he says. Herrenknecht has supplied the device in consultation with the JV, and particularly its TBM-savvy Strabag side. The manufacturer has its own personnel on site for the operation.

The system involves building the heavy cutter head section within a steel cradle in which there is a two-way jacking system. Two very large vertical jacks are the main component; these lift the whole head clear of the ground and the frame below. Smaller horizontal jacks then move the head forwards for 2m when it is lowered again onto the cradle. The big jacks themselves then move forwards and the cycle is repeated.

The back part of the central beam section of the TBM is supported with a wheeled steel frame and behind that the backup train runs on the usual wheels.

Assembly of the machine has been underway since August and the inching forward began in September as sections were added to the train. In November the main move will take place over a two-week period along the completed drill and blast section to the 30m starting stub where the machine will be able to extend its grippers and start boring.

*Above: **Conventional excavation and shotcreting work***

*Below: **TBM being moved towards the portal***

To prepare for the move, a concrete slab has also been cast within the 800m-long section to support the jacking frame as it moves along in 2m increments.

This will later serve to support a rail access system for the TBM to carry personnel and equipment for the machine. It will also bring up precast invert segments, which will continue the tunnel working floor along the entire drive.

The segments are being made by local firm Ølen Beton sited some 3.5km away and will be stored at the entrance of the access adit and loaded by a portal crane.

Alongside the track ventilation and spoil removal is being installed. For the TBM drive a conveyor system is being used from Agir.

"We are just concreting the 150m long belt extension cartridge area," says Bakketun, "and sorting out anchor points along the tunnel walls.

The belt will run the length of the drive and by the end of the drive in summer 2017 should have removed some 470,000m³ of spoil.

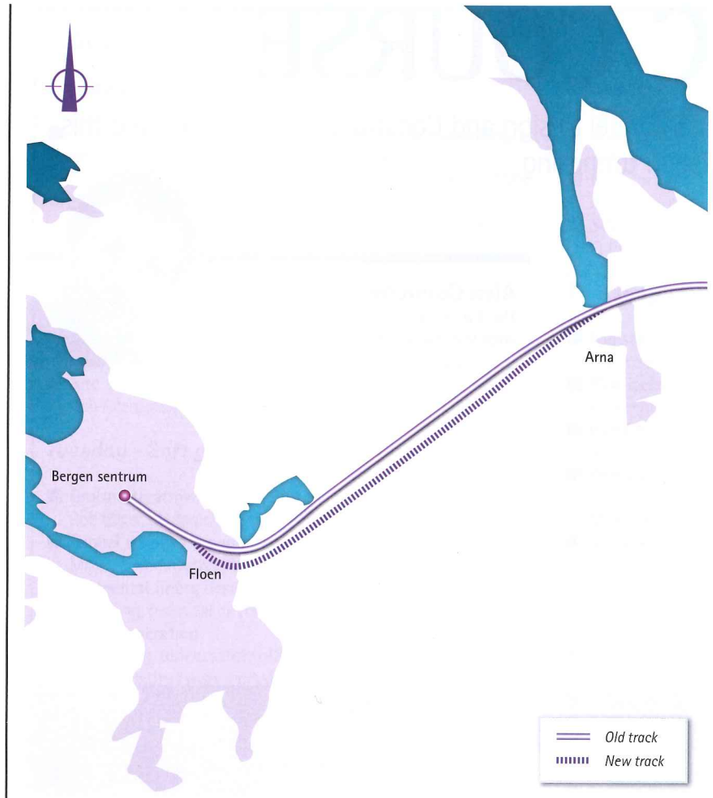
It discharges to a temporary spoil heap some 150m outside from where it will be loaded onto trucks with the wheeled loaders and onto the quarry.

"But the TBM spoil will not be crushed, the chippings are not the right size and shape for that," says Bakketun. Instead they will be stockpiled and are to be used eventually for harbour reclamation work by Bergen city authority. "They will seal and area of partly polluted seabed," says Larsen.

For the drive itself the rock is expected to be very good and the major support will be from rock anchors where necessary. These will be installed with two Atlas Copco drills mounted on the machine.

"The only possible issue is a small risk of some squeezing which was experienced in the first tunnel" says Larson. That could occur at the point of highest overburden, which is 600m.

But a major advantage of boring a tunnel only 30m away from an existing tunnel is that the geologists have an excellent way to examine the rock and predict the condition ahead says Larsen.



*Above: **Alignment map showing old and new tracks as they exit Bergen***

"The existing tunnel also means that there is unlikely to be any water," says Bakketun "because the drainage of the rock mass has been underway for decades."

The TBM is fitted with 62 disc cutters, using the bigger 19in diameter for maximum pressure. Typically for Strabag there will be a cutter disc store and workshop on site for re-edging worn discs.

The start of TBM work does not see the finish of drill and blast. Each of the cross passages has to be made. Like the rail crossover diagonals, these will be excavated with blind ends to be connected later. "Some nine of the cross passages will also have equipment rooms in them," he says, which the JV will do the concreting for.

For all the drill and blast work, operations have frequently involved reduced round lengths and half face blasting, measures needed to reduce vibration effects close to the live tunnel. That is obviously important as the blind ends are approached.

"Final breakthrough will not be done until the renovation of the existing tunnel is underway," explains Bakketun.

The plan for the project is to divert trains into the new tunnel when it is complete in 2020 says Larsen. Renovation will then be done on the 1964 tunnel, track re-laid and the cross connections broken through to establish rail links and finish the safety tunnels.

Before that of course there is lining work, which will use a "traditional Scandinavian system of polyethylene foam and shotcrete," he says. This is partly for insulation purposes in a northern climate, though the Bergen area, close to the North Sea and the tail end of the warm Gulf Stream, rarely suffers the deep cold of the rest of Scandinavia. Famously it just rains all the time.

The JV will do the lining and finishing works once the drive is complete, finishing in 2019. Track and signalling contracts will be underway at that point making the line ready for early 2020.

"We also have a lot of outside contracts for double track into Bergen and for stations," says Larsen "which must all be coordinated."

Renovation and connection work is expected to take until 2021 when the project will finally achieve its goal of double track running

BTS D&C COURSE

Alex Conacher attended the BTS Tunnel Design and Construction Course in June this year for a weeklong crash course in tunnelling

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

AROUND 90 attendees signed up to the BTS Design and Construction Course in 2015. The weeklong programme aims to provide its students with "a comprehensive introduction to all aspects of tunnelling", and judging from feedback in the Warwick University campus bars, it did not disappoint.

A surprising range of people attended the course. You could be forgiven for expecting it to appeal purely to students and young engineers, and while they certainly made up the bulk of attendees, there were more senior faces. When asked, these attendees usually said their reason for attending was to broaden their knowledge into areas related to their day jobs, but in which they had limited experience.

Course lectures

Monday - Project development

- **Trends and influences affecting UK and global tunnelling and the strategic use of underground space**
  Martin Knights, MD for tunnelling and earth engineering, CH2M
- **Financing and procurement**
  Chris Eaglen, engineering procurement and infrastructure financing planner, Transport for London
- **Stages in project development**
  Rafaella Rospo, associate, Weston Williamson & Partners
- **Project management**
  Ralph Freeston, head of station capacity programme, London Underground
- **Site investigation**
  Bob Allen, associate, London Bridge Associates

Tuesday - Soft ground tunnelling one

- **Ground treatment**
  Bob Essler, managing director, RD Geotech
- **Tunnel induced ground movements**
  Mike Devriendt, associate director, Arup
- **Segmental lining design**
  Mike King, technical director, CH2M
- **Tunnel operation**
  Les Fielding, tunnel safety officer, London Bridge Associates
- **Sustainability (with workshop)**
  Charmaine Morrell, senior sustainability advisor, Morgan Sindall

Wednesday - Sprayed concrete lining

- **History, background and overview of SCL**
  Alfred Stärk, BeMo Tunnelling
- **SCL design considerations**
  Anmol Bedi, Imperial College London
- **Specifying sprayed concrete**
  Ross Dimmock, managing director, Normet UK and Ireland
- **New developments in sprayed concrete technology**
  Colin Eddie, managing director, Morgan Sindall
- **Waterproofing**
  Ross Dimmock, managing director Normet UK
- **Monitoring**
  Alfred Stärk, BeMo Tunnelling
- **SCL process controls**
  Colin Eddie, managing director, Morgan Sindall

Thursday - Soft ground tunnelling two

- **Logistics**
  Aiden Selby, senior M&E project engineer, VVB Engineering
- **Pipe jacking techniques**
  Andrew Flowerday, managing director, Barhale
- **Hand tunnelling**
  Duncan Summers, retired
- **Risk management (with workshop)**
  Dave Terry, associate, London Bridge Associates
  Michelle King, senior risk manager, Aecom
- **Soil condition in EPB/slurry**
  Ian Morrison, technical sales representative, Morrison Mud

Friday - Hard ground tunnelling

- **Rock mass classification**
  Andrew Davis, principal engineer, Mott MacDonald
- **Hard ground temporary works**
  David Hindle, geotechnical engineer, OTB
- **Railway tunnels: operation and maintenance**
  Keith Bowers, professional head: deep Tube tunnels, LU
- **Drill and blast tunnelling**
  Mark Thomas, director, Bradenstoke Engineering
- **Shaft design and construction**
  Mahee Maheetharan, chief geotechnical engineer, Atkins
- **Tunnel equipment – TBMs and associated plant**
  Roy Slocombe, Herrenknecht

A number of the young engineers were sponsored by companies looking to upskill their staff, and students generally seemed to be seeking a route into the industry, or just looking to see if tunnelling was for them.

Additionally the BTS offered sponsored places available to the individuals who offered the best 500-word response to the question: "what do you hope to gain from the BTS Design and Construction Course?"

LECTURE PROGRAMME

The lectures covered an extensive range of topics (see box for complete list) and the complexity of the subject matter varied, so that there was something for everyone. It was comforting to not be the only person who could not keep up with some of the worked lining design examples.

Highlights definitely included Ian Morrison's vigorous lecture on the basics soil conditioning; a look back at the hand tunnelling techniques of previous generations with Duncan Summers; and Roy Slocombe's introduction to TBMs and associated plant.

Slocombe had the graveyard shift – the last presentation of the last day of a busy week – but with the help of Herrenknecht's computer animation department, he was able to liven the room up.

*Opposite: **The BTS Tunnel Design and Construction Course Class of 2015***

Workshops were also a high point, with one memorable activity seeing representatives of the client, contractor, local residents, and eco-warriors arguing over the merits of a new tunnel project. Or in the case of the eco-warriors, the intrinsic worth of the greater crested newt.

The contractors won the day.

GRADUATION

At the end of the week all attendees left with a pack of presentation slides and notes, as well as a selection of BTS publications: the 'Tunnel Lining Design Guide'; the 'Monitoring Underground Construction' best practice guide; and the 'Specification for Tunnelling: third edition'; together worth just under GBP 200 (USD 300).

The only question remaining, for those not already in the industry, was "how do I join?" (see Editor's Comment, page 3)

INNOVATION & TECHNOLOGICAL ADVANCES IN THE DESIGN OF SEGMENTAL LINING

A report on the September 2015 meeting of the British Tunnelling Society, where engineers from CH2M and Ozengi spoke on the future of segmental lining. For the full paper, please see Tunnels and Tunnelling September 2015, page 31. **Paul Perry**, newly appointed to the BTS Committee, and in charge of meetings, reports

A PACKED HOUSE was present for the BTS evening meeting by Chappell, Harding and King on the design of Concrete Lining for Tunnels at the Institution of Civil Engineers. Roger Bridge, BTS Chairman, introduced the three speakers: Mike King is currently Head of Underground Construction on Crossrail, Anthony Harding is Global Technical Leader for Tunnels at CH2M and Malcolm Chappell is a consultant and director of Ozengi, and was CH2M's Director for Tunnelling in the Pacific region with extensive experience from both sides of the fence in terms of contracting and consulting.

The meeting was set around their paper 'Continuing innovation in segmentally lined tunnels, and Malcolm started by noting that in the last 40 years the tunnelling industry had seen significant changes in technologies in TBM tunnelling and segmental linings through a range of interesting case histories. He outlined the developments achieved in 40 years and then prompted possible future developments in concrete linings, geopolymer concrete, fibre reinforcement, intelligent segments and energy segments and the trend towards larger diameter tunnels and therefore larger segments.

Anthony then took over to put some technical information behind these ideas. He discussed plain concrete, aspects rations and the various load cases that are considered in terms of handling and the like when considering the need for reinforcement within the lining. He outlined the use of geopolymer, testing and their current use in schemes being limited to date. Anthony attempted to be persuasive on their performance and benefits referring to cost. This enthusiasm was held back by the lack of mature supply chains currently. He went onto to cover macro synthetic fibres and eventually the reduction and possible elimination of the use of bolts in tunnel lining. This would assist with an easier installation and corresponding reduction in TBM crew sizes. He also described the issue of "intelligent structures" that monitor performance automatically to assist when maintenance is required. He went on to elaborate on energy recovery systems built into the lining and concluded with further thoughts on future trends in larger tunnel and segment sizes.

Mike then continued with an opening stating that he wished to promote debate without having all the answers with a series of quotes and prompts set around a number of sources including Tony Blair and Margaret Thatcher. He discussed what enables innovation and the awareness of its importance as well as an appreciation of the cost to avoid British Tunnelling lagging behind the rest of the world. He described the need for Technical Peer Review to give confidence in the industry and suggested the need for a group to lead on Tunnelling and Innovation to ensure this remains in the fore. He ended by saying that the tunnelling industry has the ability to manage the risks and ensure that improvements to segmental linings continue at the same pace as they have in the last decade.

The Chair then took control of an active Question and Answer session with subjects such as who owns the cement industry through to the use of tunnel linings without reinforcement being common practice in the past.

Comparisons were made with Sprayed Concrete Tunnel lining and the traditional methods of timber headings and SGI linings from a number of experienced tunnel engineers in the room. The Chair drew the meeting to a close with the traditional applause, thanking the speakers for their presentation and no doubt further discussion ensued in the institution's bar afterwards

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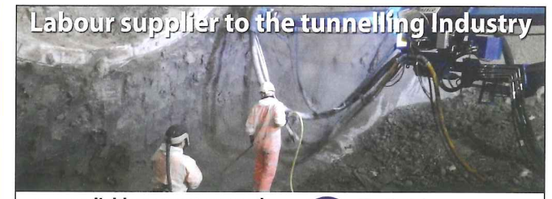

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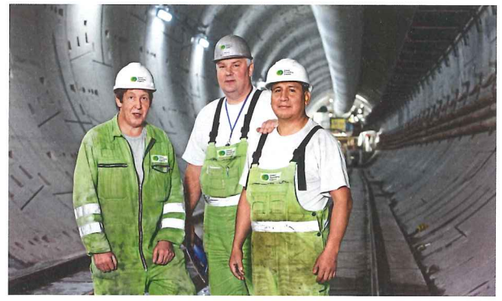

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What's on

2015

25th World Road Congress
2-6 November 2015
Seoul, South Korea
The World Road Congress has been held every four years for more than 100 years. Since the first meeting in Paris in 1908, it has toured the member countries of the non-government organization, Permanent International Association of Road Congresses (PIARC).
www.aipcrseoul2015.org

Controlling exposures and health risks in construction
10 November 2015
Birmingham, UK
The Breathe Freely campaign has been launched recently with a view to raising awareness of the occupational health issues related to respirable materials.
www.breathefreely.org.uk

2015 Trenchless Technology Road Show
17-19 November 2015
Richmond, BC, Canada
Hosted by the North American Society for Trenchless Technology's British Columbia Chapter and the Centre for Advancement of Trenchless Technologies, this show will consist of technical presentations and exhibits covering the latest advances in trenchless technology.
www.trenchlessroadshow.ca

TBMs in Difficult Ground
18-20 November 2015
Singapore
TBM DiGs 2015 is to be held in Singapore, jointly organised by the universities and supported by the tunnelling community worldwide, interested in TBM tunnelling technologies. The organisers would like to welcome researchers and practitioners to the event.
www.tbmdigs.org

ITA Tunnel Awards
19 November 2015
Hagerbach, Switzerland
The International Tunnelling Association has launched its own independent awards to recognise industry achievements.
www.awards.ita_aites.org

Third Arabian Tunnelling Conference and Exhibition
23-25 November 2015
Dubai, UAE
This conference is the industry's opportunity to share the knowledge, projects and application experiences, and provide you the opportunity to hear what others have to say. Case studies, that show real-world applications as well as the implementation of new technologies will be presented.
www.atcita.com

Scotland Build 2015
25-26 November 2015
Glasgow, United Kingdom
Taking place at the Scottish Exhibition and Conference Centre (SECC), Scotland Build 2015 is the ideal opportunity for your organisation to get involved in Scotland's booming construction industry and to access major developers, contractors and suppliers from across Scotland and around the world.
www.scotlandbuildexpo.com

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

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

2016

International Symposium on Tunnel Safety and Security
16-18 March 2016
Montreal, Canada
Tunnel safety and security is a challenge for both private and public sectors. ISTSS provides a forum to discuss current practice and emerging trends and research in safety and security. *www.istss.se/en*

NASTT's No Dig Show
20-24 March 2016
Dallas, USA
The overall No-Dig Show program is focused on one objective: helping you maximise your investment in trenchless technologies, services and applications. If you sell trenchless products and services you'll want to be sure to exhibit.
www.nodigshow.com

Bauma 2016
11-17 April 2016
Munich, Germany
The 31st meeting of the world's largest trade fair for construction machinery, building material machines, mining machines, construction vehicles and construction equipment returns to its traditional home: the Neue Messe Munchen exhibition centre in eastern Munich.
www.bauma.de/en

International Symposium on Submerged Floating Tunnels and Underwater Structures
20-22 April 2016
Chongqing, China
This event, organised by the National Engineering Laboratory for Highway Tunnel Construction Technology, the China Institute of Mechanics, the Chinese Academy of Sciences, and the University of Naples will cover all topics from conceptual design up to operational emergency rescue.
www.cmct.cn

World Tunnel Congress and North American Tunnelling conference 2016
26-28 April 2016
San Francisco, California
The 2016 World Tunnel Congress (WTC) and the 39th General Assembly of the International Tunnelling and Underground Space Association (ITA) will be held in conjunction with the UCA's North American Tunnelling conference. Bringing the events together in the US is unprecendented.
www.wtc2016.us

Underground Construction Prague 2016 and EETC
23-25 May 2016
Prague, Czech Republic
Delegates are cordially invited to the thirteenth Underground Construction (UC) Prague Conference. Past conferences confirmed that the Prague conference thanks to its scientific and social programmes found a firm position among European tunnelling events.
www.innotrans.com

Swiss Tunnel Congress 2016
15-17 June 2016
Lucerne, Switzerland
The annual Swiss Tunnel Congress (STS) is organised by the Swiss Tunnelling Society and is the premier event for tunnelling in Switzerland. Approximately 800 delegates attend from around 15 nations to take in the high quality presentations and enjoy the technical excursions to construction sites within Switzerland, as well as the surrounding countries. The STS is broadening the spectrum of topics this year.
www.swisstunnel.ch/en

GeoChina International Conference
25-27 July 2016
Shandong, China
This conference will provide a showcase for recent developments and advancements in design, construction, and safety Inspections of transportation Infrastructures and offer a forum to discuss and debate future directions for the 21st century. Conference topics will cover a broad array of technical issues.
www.geochina2016.geoconf.org

Innotrans
20-23 September 2016
Berlin, Germany
InnoTrans is the leading international trade fair for transport technology and takes places every two years in Berlin. Sub-divided into the five segments Railway Technology, Railway Infrastructure, Public Transport, Interiors and Tunnel Construction.
www.innotrans.com

2017

World Tunnel Congress 2017
9-16 June 2017
Bergen, Norway
The theme of the 2017 WTC is 'surface problems - underground solutions'. The Norwegian tunnelling industry produces tens of kilometres of drill and blast tunnel every year and is keen to share its expertise with attendees.
www.wtc2017.no

AFTES International Congress 2017
13-15 November 2017
Paris, France
The main French engineering event is themed 'the value is underground' for its 2017 show and will be held in the French capital at 'Le Palais des Congrès de Paris'. *www.aftes.asso.fr*

The British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Regular BTS monthly meetings are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month. In recent years, the BTS Young Members (BTSYM) group has also begun hosting events.

The Abu Dhabi Strategic Tunnel Enhancement Project (STEP)
19 November 2015
The Strategic Tunnel Enhancement Project (STEP) consists of 45km of gravity sewer and 43 km of link sewers taking sewerage flows out of Abu Dhabi city to a new treatment plant. The talk focuses on the challenges of designing and constructing the deep gravity sever, which started at a depth of 24 m in the City and ended at 80 m depth with a diameter of 6m at the new treatment works. Designing such a sewer tunnel to have a long service life in the severe exposure conditions of the Gulf illustrates how modern developments in service life design and tunnel design can be applied to such projects.
Speakers: Shahzad Orakzai of the Abu Dhabi Sewerage Services Company, Richard Graham of Salini Impregilo, and Carola Edvardsen of Cowi

BTS Underground Health and Safety Course
23-24 November 2015
The Health & Safety Course is organised and run by the British Tunnelling Society (BTS), an Associated Society of the Institution of Civil Engineers. The purpose of the course is to provide a comprehensive introduction to Health & Safety in tunnelling. It has been decided that the two day format of the last five years will be repeated to allow more time on specific subjects and also to include more discussion and debate. Booking is now available on the BTS website.
Fees: BTS Members: GBP 100; Non-Members: GBP 150

BTS Christmas debate
10 December 2015
The traditional end of year debate will this year argue the proposition "This house believes that developments in recent years relating to sprayed concrete lining thicknesses is heading in the wrong direction, noting that sprayed concrete lining has managed to double the lining thicknesses in the last ten years". After hearing the arguments for and against, some more serious than others, a vote from the floor decides the issue.
Speakers for and against have yet to be confirmed

Sochi Tunnel, Russia
21 January 2016
The January meeting will describe the Sochi Tunnel, built for the 2014 Winter Olympics on the Black Sea coast of Russia, describing the design approach, laboratory and field testing to validate the design parameters and the construction works which took place from February 2011 to January 2014.
Speakers: Carla Zenti of Bekaert Maccaferri Underground Solutions, and Giovanna Cassani, technical director for Rocksoil

The history of the Davy Lamp (joint BTS-MinSouth event)
18 February 2016
The presentation will be about the History of The Davy Lamp and will be given by a mine rescue professional who was involved with the Chile Mine Rescue It should prove to be of great interest to both mining and tunnelling professionals.
Speaker to be confirmed

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

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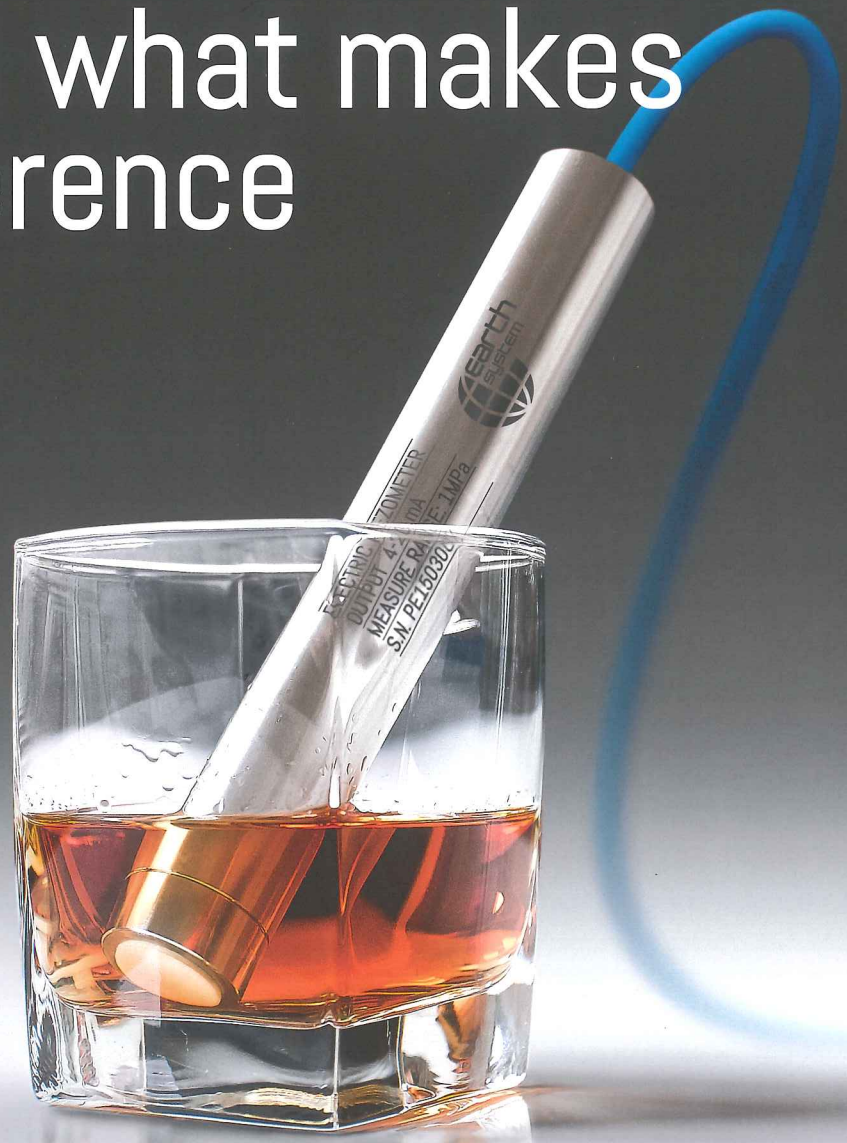

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