

INTERNATIONAL EDITION  
March 2017

# Tunnels

AND TUNNELLING

## ISTANBUL'S MACHINES

*A refurbished EPB shield working  
in Turkey's largest city*



## Conquering

Connecting Norway by rail: 5 Herrenknecht Hard Rock TBMs are on the move for **45 km of new first-class rail tubes** at the New Ulrikentunnel and Follo Line projects.

## Toughest

Biting its way through the Scandinavian stone, the TBMs are facing the absolute **hardness test** when dealing with up to **350 MPa** rock strengths. Equipped with excavation tools for such a demanding mission, the Herrenknecht TBMs will complete all their tasks.

## Hard Rock

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## Pioneering Underground Technologies



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## CALLING DRIFTER



In this issue we have a comment article written by Martin Knights, a past president of the International Tunnelling Association calling on engineers to “value their signature” and think about what they are putting their names to when they sign off on something. It starts on page 18 and is well worth a read.

But there are instances when you might not want to put your name to something.

A number of years ago there was a regular section in *Tunnels and Tunnelling* that we called Drifter. The article was written anonymously by whoever wrote in to us with some irritation about the state of a project, practice, or the industry at large. The only thing the authors had in common was a desire not to put their name to the article.

Past topics have included “half the money on site investigation is wasted”, “we can

### Alex Conacher

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



claim little or no credit for improvement in site communication” or even “tunnellers must take to social media to promote the industry”. But there have been many more.

The revival of drifter is a topic that has been coming up more regularly in conversations at the bar. We have seen clients’ paranoia grow, bringing with it the excessive gagging of engineers over even non-controversial topics.

In the UK the rise has been relatively sudden. On major projects, if you are not seconded to the client, you are now often not allowed to speak to the press. This is not brand new, but there has been a change in the obstinacy of some clients, while in other countries it is a more traditional state of affairs that the client or the state controls who has the right to comment or what is an appropriate area of discussion.

Drifter frees you of the fear of retribution from your paymaster, so if you or a colleague have anything you want to say but can’t, email me and take up the role for a month. Your name will not appear in print but you will get your message out to the readers and wider industry.

Drifter, I look forward to hearing from you 

### Cover

This month's cover shows a refurbished EPB TBM in operation under Turkey's largest city, Istanbul



### This month...

#### 30 YEARS AGO

Financial arrangements appear to be baulking the start of the AUD 435M immersed tube road tunnel that would provide the second road traffic crossing for Sydney Harbour in Australia. The Australian government has insisted that the project can only be undertaken if it is a self-financing entity and also that the harbour bridge toll, that would contribute, could not be increased to more than AUD 1.

*Tunnels and Tunnelling*, February 1987 p.13

#### 40 YEARS AGO

As part of a long term plan to preserve London Transport's oldest underground tunnels, mechanical cleaning and pressure pointing techniques are being used to renovate inner brick linings. Some of the soot-encrusted tunnels are more than 100 years old and date back to the steam trains, which for many years were the established means of transport in London's complex underground system.

Despite their age the tunnels are basically sound; however, deterioration of the inner surface of the tunnels now necessitates specialist attention to preserve them. Cementation Ground Engineering has a GBP 80,000 contract which is scheduled to last 30 weeks for preserving the tunnels between Paddington and Bayswater.

*Tunnels and Tunnelling website*, February 1977 p.17

### Next issue

In the next issue of *Tunnels and Tunnelling International* we have an article on Spain's Bolanos Tunnel project, a British Tunnelling Society report on over-tunnel construction at Amsterdam Station and a disc cutter comparison article from China



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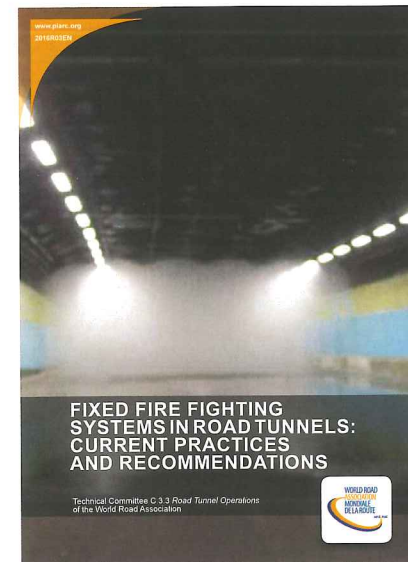
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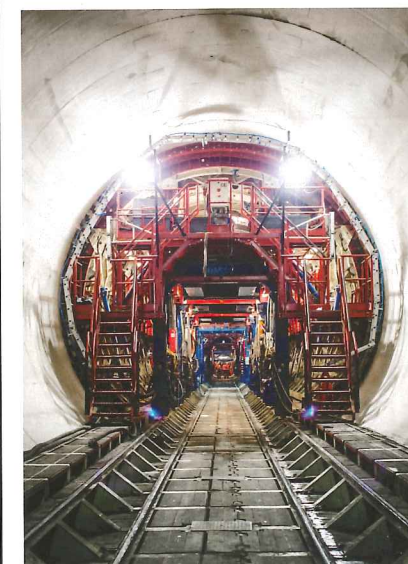
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**Adam McKnight**  
Project Manager Engineer  
Upper Trinity Regional Water District

Chris Knott, Director of Business Development/ Estimator at BTrenchless always looks forward to NASTT's Educational Fund Auction & Reception. The auction is a great place to catch up with fellow peers and network in a fun, laid-back atmosphere.

One reason I enjoy this show every year is due to the quality time spent networking with contractors and engineers in the Exhibit Hall. I could be talking with someone about their project and end up showing them a way to make their project go smoother or I might be simply educating new faces in the trenchless technology field. A good way to make lasting relationships in the industry.

**Luc Lupien**  
Director of U.S. Western Region Operations  
Sanexen Environmental Services Inc./Aqua-Pipe

## BSI PUBLISHES TEMPORARY WORKS CODE OF PRACTICE...



A PAS is not a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard. The PAS process enables a code of practice to be rapidly developed in order to fulfil an immediate need in industry. A PAS can be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

A spokesperson for BSI said, "PAS 8811 was sponsored by High Speed Two (HS2) Limited and the Temporary Works Forum (TWf), and defines major infrastructure client responsibilities with regards to temporary works. It also recommends a common set of procedures for use by UK major infrastructure

clients. BSI engaged with a number of construction industry stakeholders to identify areas in which it was felt that the industry could benefit from further standardisation. "Procedural controls for temporary works are covered in BS 5975:2008+A1:2011, Section 2 and are widely used across the industry. Whilst this standard provides the basis for contractors' procedures for temporary works, it does not provide explicit guidance for clients. Consequently, client organisations have tended to develop

individual requirements resulting in a variety of approaches, which have created confusion and complexity particularly with respect to approval and compliance, with adverse impact on administrative costs and programme."

Ant Burd, Head of the built environment sector at BSI, said: "The aim of PAS 8811 is threefold: to establish a unified approach to client involvement in temporary works across all stages; to eliminate unnecessary procedures and conflicts in order to achieve clarity; and to minimise delays during compliance and approvals processes and other necessary procedures."

The spokesperson added: "This PAS complements, and is intended to be used in conjunction with, BS 5975, Code of practice for temporary works procedures and the permissible stress design of falsework, expanding areas where there is limited information provided for major infrastructure client requirements.

"PAS 8811 does not cover the contractual responsibilities of clients, suppliers or contractors. Where there are relevant existing standards or industry documents, this PAS refers to these and is not intended to replicate existing material."

BSI (British Standards Institution) is a business standards company. Formed in 1901, BSI was the world's first National Standards Body and a founding member of the International Organization for Standardization (ISO).

**Top left: The front page of the code of practice**

### ...and revises engineering drawings standard

**GREAT BRITAIN —** The British Standards Institution (BSI) has revised BS 8888:2017 - Technical product documentation and specification. The latest version is a comprehensive update to the UK's national framework standard for engineering drawings and geometrical tolerancing.

Dan Palmer, head of market development for manufacturing and services,

said, "BS 8888 is the descendent of the world's original engineering drawing standard, BS 308, and the revised standard is aimed at engineers who were trained using BS 308 as well as new users.

"The benefits of BS 8888 include improved productivity, reduced costs, and enhanced quality. For industry, this can mean fewer disputes over compliance or noncompliance of components, reduced scrap and re-works rates, and fewer queries due to incomplete specifications."

BS 8888 defines the requirements for the technical specification of products and their component parts.

The standard explains the way in which engineering drawings outline and present these specifications, and covers all of the symbology and information that engineers and designers need to include on their drawings, whether they are produced in 2D or in 3D, created using CAD systems and 3D modelling.

A spokesperson added: "The updated standard is

expected to be particularly useful to mechanical engineers, engineering designers, and design engineers in the UK, working in engineering and manufacturing companies, particularly in defence, aerospace, automotive, rail, nuclear and other general manufacturing sectors. Essentially, any engineering drawing should comply with the requirements of BS 8888. Independent design consultancies or design agencies are also set to benefit from BS 8888."

## PORT MANN WATER SUPPLY TUNNEL NOW IN SERVICE

**CANADA** — After almost six years of construction, Metro Vancouver's CAD 240M (USD 182.62M) Port Mann Water Supply Tunnel is now online, the authority said on 20 February.

The Port Mann connection is one of the key links between Metro Vancouver's watersheds and the communities south of the Fraser River. Replacing this crossing was the first in a series of major water transmission system upgrades throughout the region.

Located more than 30m under the Fraser River bed, the new tunnel more than doubles the capacity of the old water main and provides enhanced earthquake and river erosion resiliency to help ensure the continued delivery of drinking water to Metro Vancouver residents.

"This was one of the most challenging and rewarding projects we've ever built," said Darrell Mussatto, chair of Metro Vancouver's Utilities Committee. "Our engineering and construction team came up with innovative solutions to tunnel through difficult terrain, at exceptional depths and under extreme groundwater pressures."

The Port Mann Water Supply Tunnel consists of two 60m deep shafts - one in

Coquitlam and another in Surrey - connected by a 1km-long, 3.5m-diameter tunnel housing a 2.1m-diameter steel water main. A new valve chamber was built at the top of each shaft to allow the new tunnel to connect with the existing land-based water mains on either side of the river.

Construction started in the spring of 2011, when ground was broken for the south shaft.

Tunnelling began in February 2014 and achieved breakthrough in June 2015. Installation of the water main inside the shafts and tunnel was completed in July 2016 and the valve chambers were finished in January 2017.

The tunnel had to be located deep underground to maximize its earthquake resilience, and tunnelling 30m below the bed of the Fraser River posed significant challenges.

Engineers had to overcome difficult soil conditions and the highest groundwater pressures ever observed in Canadian soft ground tunnelling.

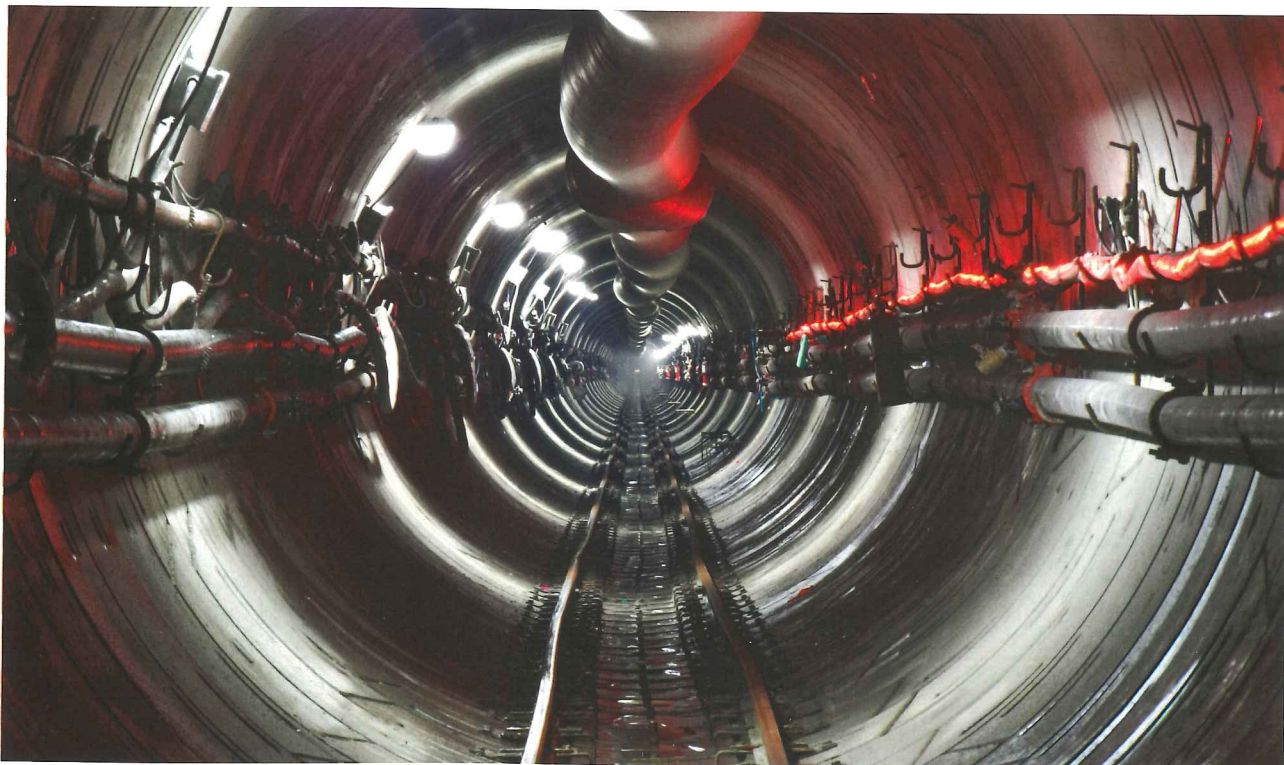
The soil deposits under the Fraser River consist of several different geologic layers. Some places have sand, gravel and clay, while others have dense, glacial soil strewn with immense granite boulders.

These soil conditions, combined with the high groundwater pressures, required an advanced, custom-designed TBM to complete the tunnel under the river. At one point, engineers had to inject liquid nitrogen from an in-river work platform to freeze and harden the soil at the front of the tunnel boring machine so that it could be repaired.

"This was an extremely complex project that took a lot of skill and creativity," said Metro Vancouver board chair Greg Moore. "The insights and experience gained will benefit future tunnelling projects in Metro Vancouver, throughout Canada, and abroad."

The project team consisted of Metro Vancouver and McNally Construction Inc.-Aecon Constructors Joint Venture, with construction management provided by Hatch Infrastructure. Design and engineering services were provided by the Fraser River Tunnel Group, which comprised Ausenco Engineering Canada, McMillen Jacobs Associates, and Golder Associates.

Metro Vancouver's Port Mann Water Supply Tunnel Project received the "2016 Canadian Innovation Project of the Year Award" from the Tunnelling Association of Canada.



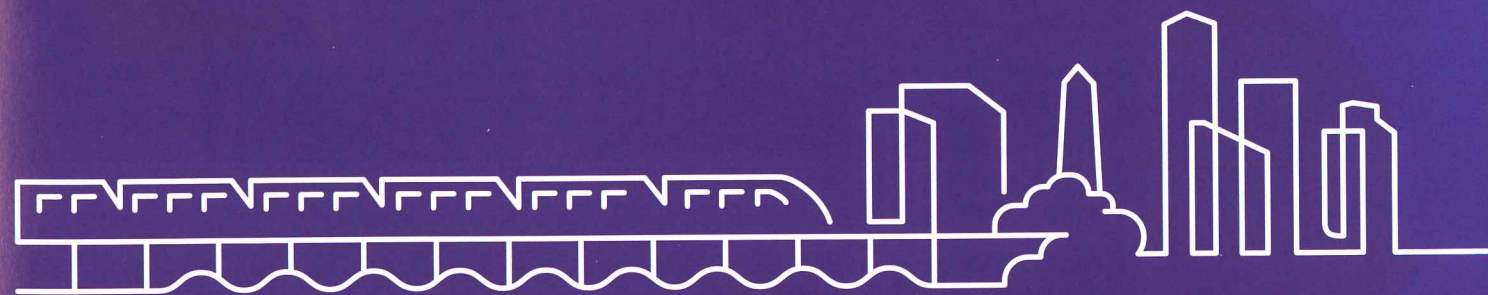
**Above:** The new tunnel more than doubles the capacity of the old water main and is more resilient to earthquakes

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## TUNNEL CONSTRUCTION IS COMPLETE ON COPENHAGEN'S CITYRINGEN

**DENMARK** — The four TBMs excavating Copenhagen's Cityringen have completed their drives, twin tunnels comprising 15.5km in length, client Metroselskabet announced 20 February.

Launched in 2013 the TBMs faced lime, gravel, sand and stone along with major challenges like passing below historic buildings, and difficult geological conditions such as the valley next to City Hall. Tunnels have an id of 4.9m.

Prime minister Lars Løkke Rasmussen

made a brief speech at the milestone celebration: "I have followed the metro construction closely.

"From my apartment in Nyhavn, I have been able to hear it. When I am walking the dog, we often walk past Kongens Nytorv, and from my office at Christiansborg, I can almost wave to the crane operator.

"It will be a huge advantage to get some traffic away from congestion and under ground."

The Cityringen will open in July 2019, connecting Østerbro with Nørrebro, Frederiksberg, Vesterbro and Downtown. The line will have 17 new stations in central Copenhagen.

The contractor responsible for civil construction work is the Copenhagen Metro Team JV comprising Salini Costruttori, Tecnimont and Seli. Cowi, Arup and Systra handled vibration analysis as well as all other design and engineering works.



**Above:** Prime Minister Lars Løkke Rasmussen, Mayor of Copenhagen, Frank Jensen, and Frederik's mayor Jørgen Glenthøj, all to celebrate the tunnel work is now completed. Photo: Marie Hald

### HS2 gets Royal Assent, ministers and executives react

**GREAT BRITAIN** — The UK's new north-south rail link has made it through the final round of parliamentary debate. The High Speed Rail (London – West Midlands) hybrid Bill – essentially the planning application for HS2 – received overwhelming support from MPs. In the Bill's third reading in the Commons MPs voted 399 to 42 in favour. In the Lords,

the figures were 386 to 26 in support of the Bill passing.

David Higgins, chair of HS2 commented: "Achieving Royal Assent for Phase One of HS2 between Birmingham and London with such significant parliamentary support, is a monumental step in transforming rail travel in Britain. We have a long journey ahead of us to build the railway and secure permission for Phase Two to make sure that the full benefits of HS2 are realised. This journey will see

businesses right along the route benefit from greater access to the skills, markets and professional services they need to succeed in today's global market. It will directly create some 25,000 jobs as well as forcing the pace of innovation in the construction industry.

Transport Secretary Chris Grayling took the opportunity to wave the flag, and said: "Getting the go-ahead to start building HS2 is a massive boost to the UK's future economic prosperity and

a further clear signal that Britain is open for business. "HS2 will be the world's most advanced passenger railway and the backbone of our rail network. Royal Assent is a major step towards significantly increasing capacity on our congested railways for both passengers and freight; for all.

At the same time as the announcement, multiple programmes worth GBP 70M were announced that intend to mitigate negative impacts of the controversial project.

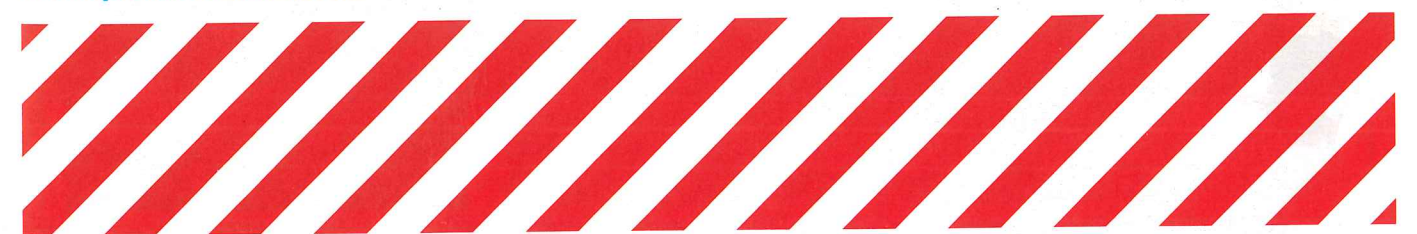
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## BRITAIN THINKS DEEP

**GREAT BRITAIN** — A new organisation to consider how we plan, manage and realise underground real estate has been launched in the UK. Think Deep UK (TDUK) is the baby of a group of built environment experts. At a launch event in London in February, cross-disciplinary support was the talking point.

The group gives its mission as “to promote awareness of the value of underground assets and to create a policy framework that can enable its fair use. To inform and guide the general public, decision makers, politicians and professionals how the use of urban underground space can create better cities with socio-economic benefits for society. To encourage planners and decision makers to think deep.”

Specifically, it has five goals:

- To promote the importance of sustainable and compatible use of urban underground space an enhance awareness of the value it can generate for cities
- To create a three-dimensional spatial planning strategy and define processes for safeguarding spaces underground
- To be a facilitator bringing together interested organisations and individuals with a singular campaigning voice
- To improve plans for future underground infrastructure and help co-ordinate a multi-disciplinary approach

- Develop guidance and best practice

The groups one year plan primarily involves three workshops, each of which will result in a white paper from the group. The first will be a 3D modelling occasion, then policy/legislation and finally an ‘opportunities’ workshop (blue sky thinking). These three events will inform the group’s direction going forwards.

Petr Salak, speaking on behalf of Think Deep UK said: “We want to create a common vision for urban underground space to transform our cities for the benefit of society. To do this we need a master plan for underground space – this needs to be developed by experts across multiple disciplines, reforming policy to ensure a proactive, not reactive approach.”

Former ITA president Martin Knights said: “It is absolutely essential to get all of these different sorts of people involved. I would like to see more city planners and people from that side.”

London Underground’s engineering profession head for deep tunnels Keith Bowers said: “This challenges the way we think, how to develop cities as a whole and not just metro or sewer networks individually. The industry should embrace it as a challenge – London should in particular. If this group has a particular value for me, it is as a lobby to shape the future of cities.”

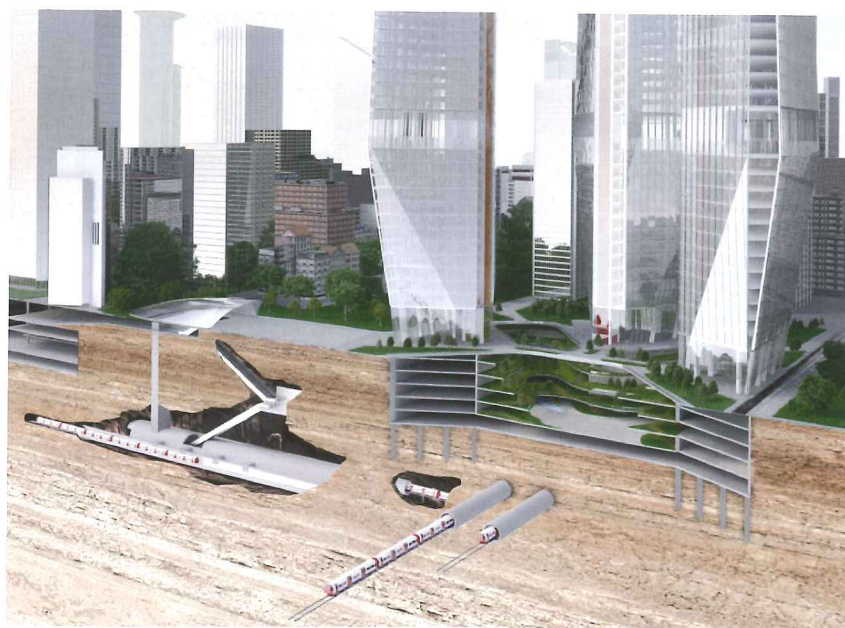
Han Admiraal of the ITA Committee

for Underground Space said: “People are not thinking enough about underground space. Politicians are fascinated by the potential and want to address it with us. We have a tendency to rely too much on political leadership on this issue, there is a lack of demonstration from our side. It is important to offer politicians the end-use benefits. Which is what they are really interested in.

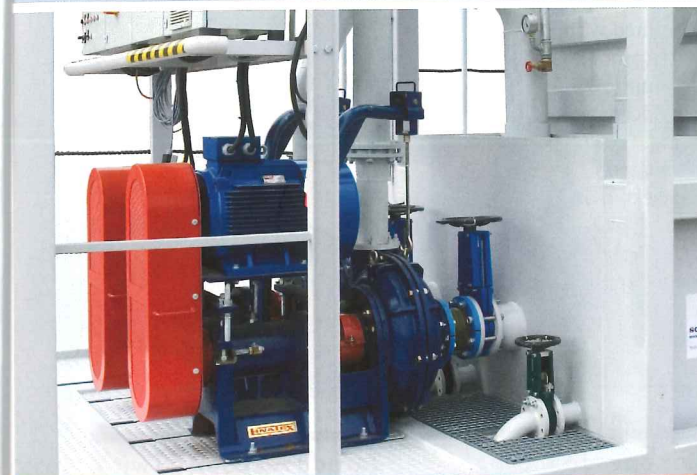
“No longer will you hear me quote the successes of the past as rationale for the future, we now live in an era where human activities are influencing the Earth’s geology and ecosystems, we are changing the urban fabric beneath our cities. We need to think deep about our actions and the opportunities that lie below the surface”.

British Tunnelling Society chair Mark Leggett said: “The reason the BTS is endorsing this project is that the case for underground space has never been clearer, we need a sea change in our thinking about and use of underground space to meet the needs of society. The equation absolutely points to tunnelling.”

Alun Thomas, head of tunnelling at Ramboll said: “Hopefully we are reaching a point where we will be pushing an open door regarding underground space. The pressure in our cities means that on a political level we will have to use space coherently, not just for single end-uses. We have to get multipurpose underground space, that is the step change. I passionately believe in this.”



**Above:** 3D illustration of underground space **Top right:** Brian Collins delivers the opening address for the TDUK launch **Bottom right:** Guests at the TDUK launch hear how cities can be more sustainable, resilient and liveable by thinking deep



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## PJA LAUNCHES INTRODUCTION TO PIPE JACKING

**GREAT BRITAIN** — The Pipe Jacking Association has published an updated introduction to pipe jacking and microtunnelling. The 24 page publication provides an overview of pipe jacking and its benefits, with over 50 updated computer graphics and illustrations. Topics covered include applications and benefits, site investigation, design and construction methods to include details of excavation systems available, pipe jacking pipes, and jacking lengths, loads and tolerances.

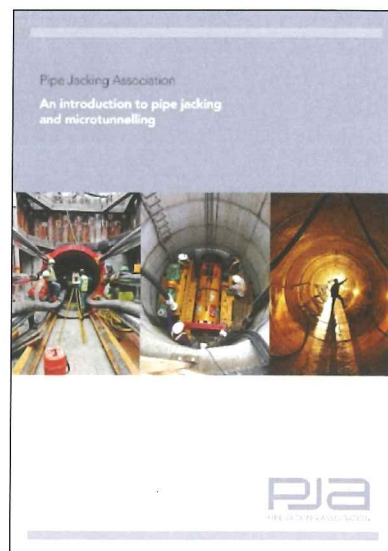
A PowerPoint presentation covering the document's content is also available on the PJA website, which, together with downloadable lecture notes, can form a part of CPD programme.

Pipe jacking is used extensively for the installation of non-disruptive utility

tunnels for gravity sewers and drainage in urban areas as well as for under obstructions such as major roads and motorways, railways and rivers and canals. It also used for the provision of conduits for gas, water, electricity and other utilities.

Pipe jacking can deliver considerable environmental benefits compared with open-cut pipe installation as carbon emissions can be reduced by up to 75 per cent, traffic congestion is reduced, and long term damage to existing infrastructure is mostly eliminated.

An Introduction to pipe jacking and microtunnelling (ISBN 978 -1-5272-0331-9) is available from the Pipe Jacking Association [www.pipejacking.org](http://www.pipejacking.org). It costs GBP 25 and PDF copies can be downloaded from the website.



### LETTER TO THE EDITOR

I am getting increasingly disturbed by the trend to have thicker and thicker tunnel linings (and more and more excavation, of course) with associated increasing of carbon footprint. For example, introduction of sandwiched sprayed membranes has led to "double lining" in terms of SCL thickness. Is this really progress?

With the old goal of minimising quantities having disappeared we are seriously in danger of pricing projects, or at least tunnel options, out of the market.

The history is that for decades tunnel designers have been trying to optimise costs and so linings became more and more economical based on practical results. In the past decade though the "thickness" curve has dramatically shot upwards; our linings are now often twice as thick as the historic optimum. With the SCL example this is usually based on ignoring composite action because of the slip surface created by the sprayed membrane. Obviously whole life service and durability are other considerations that have contributed but I seriously question the trend. Two routes appear to be available to get improvement:

- 1) Tests and analyses indicate a composite design approach is possible based on laminate glass theory (watch for forthcoming papers to be published in the proceedings of WTC 2017, Bergen; A. Pillai et al on load sharing tests and H. Jung et al on a proposed design approach). If accepted this will give worthwhile savings compared to current practice.
- 2) Use integral waterproofing for the secondary lining, by having a pore-blocking concrete additive in the mix, and delete the sprayed membrane. Depending on water pressure, this could typically result in the same thickness as we used to have (there being bond between the two layers) and by deleting a trade there will likely be programme improvements. The additive should also satisfy durability concerns in most cases.

David Caiden, director, Arup

### Bids open for Fort Wayne combined sewer overflow tunnel

**USA** — The Fort Wayne City Utilities department opened the bids for the Three Rivers Protection and Overflow Reduction Tunnel on 16 February.

S.A. Healy-Salini Impregilo is the lowest bidder with USD 187,963,000. The city will assess the bids and said it will announce the award in three to four weeks. The main tunnel will be approximately 5-miles (8km) long and will be located at depths of 160 to 180ft (48.7 to 54.8m), in bedrock. This will be a TBM drive with a diameter of 16-18ft (4.8 to 5.4m).

As part of the tunnel works, a mile of consolidated sewers will be constructed by open cut and trenchless methods near surface sewers that will collect combined sewage from the existing sewer system and connect to drop shafts to the main tunnel.

There will be two miles of relief sewer at the south end of the tunnel that will be constructed by open cut.

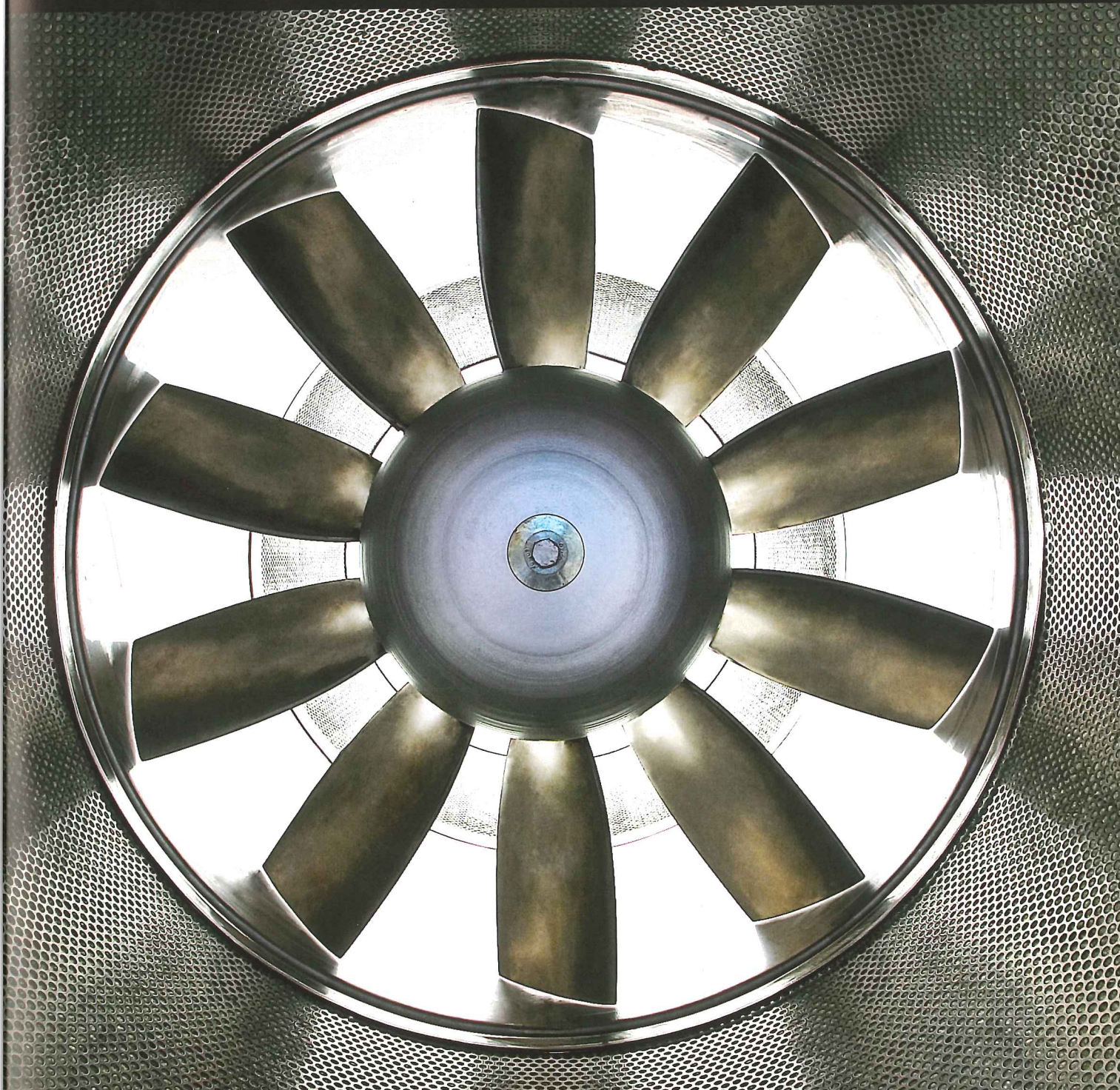
### Tarada recognised with third Fellowship

**GREAT BRITAIN** — Fathi Tarada, director of ventilation specialist Mosen has been awarded a Fellowship from the Institution of Civil Engineers (ICE). The award adds to Fellowships from the Institution of Mechanical Engineers, awarded in 2001 and the Institution of Fire Engineers, awarded in 2012.

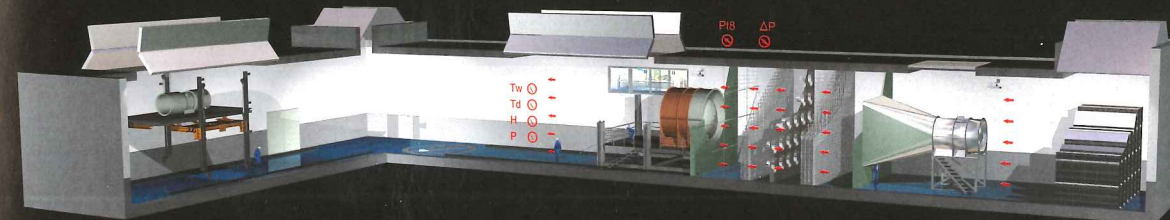
Tarada said that he thinks he might be the first person to assemble this triad of honours, although he has not confirmed this.

Of his latest award, Tarada added: "I am delighted to receive a Fellowship from the ICE in addition to my existing Fellowships. I am committed to use my Fellowships to improve fire safety in complex buildings and underground infrastructure worldwide. My sincere thanks to my sponsors: Tim Broyd, ICE president; Les Fielding, IFE Fellow and Tony Caccavone, ICE Fellow."

Tarada is working on the Delhi Metro; Lucknow Metro; Singapore Metro; Hackney Town Hall; Ethiopia AKH Railway; and Tottenham Hale Station Upgrade.



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**Left:** Crews punched through on 28 December 2016, in Ottawa's LRT tunnel. The western portion of the tunnel has met the eastern portion, and there is now a contiguous 2.5km tunnel. Complete tunnel excavation is on track for the end of February

PHOTO:  
CITY OF OTTAWA

# VALUE YOUR SIGNATURE

**Martin Knights**, an independent consultant and former president of the International Tunnelling Association, asks what lies beneath your signature in this reaction to a comment at the recent Harding Memorial Lecture, hosted by the British Tunnelling Society

**T**HEY SAY THAT YOU should be careful for what you wish, so what do we consciously wish for in a signature? At a recent BTS evening event the audience was reminded of the underlying values that support the act of adding your signature to a document and I reflected on the wider implications of the 'signature'; both personal and corporate. Are there growing influences that have degraded the symbolic act of signing and do they detract from the worth of the signature? Have contemporary processes, systems and layers of checking and assurance been a poor substitute for the intrinsic importance of pledging your commitment and all the responsibilities that are implicit in *lending* your signature? Have we forgotten to recognise the worth of the professional Engineer who is signing the document and, importantly, why the need to stand back and reflect on this 'loss' of recognition?

Professionals are required to follow codes of ethics, integrity and importantly to know our limits as well. The signature should be a reflection of what we are, i.e., our training and experience, knowledge, professionalism and reputation. Surely these values are inherent and embedded in a signature representing a confirmation, agreement, and commitment of the document that is being signed.

Well, I think that we all acknowledge that in signing a document we subconsciously have some sort of implicit knowledge of the responsibilities and potential liabilities in doing so. But it's a sort of misty acknowledgement, and often a fleeting thought, subliminally pushed to the back of our minds because of the need to deal with responsibilities, schedules, deadlines and diaries; part of the contemporary workload being the layers of oversight influenced by 'robust' project governance procedures, i.e., *checking of the checkers*. More will be written on this later.

When we send e-mails with automatic signatures are we aware whether we are making a personal comment and or a statement on behalf of the body that we represent? The instinctive reaction to respond with an unthinking/unclear informal exchange (because it's easy and tempting to do so) probably creates more e-mail exchange. If the sender had thought more about the content of the original message, along with a conscious awareness of the act of adding an automatic signature, would this be a required behaviour to help to raise the trust and value of a signature. I think this was the case when letters were the norm where a lot more consideration was given to the content of memos, messages and letters.

A senior tunnelling colleague recently drafted an article for a technical journal where he stated that currently there actually wasn't an acute shortage of skilled engineers; it was just that the industry had actually placed the right talent in the wrong roles

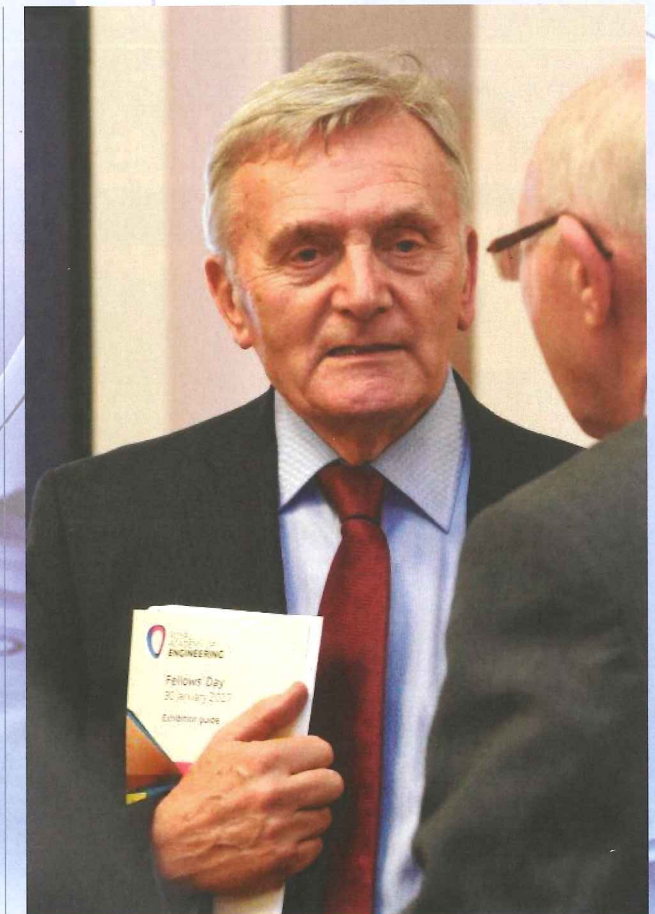
and not necessarily in the right organisations (reminding the author of a famous Eric Morecombe and Andre Previn sketch). My colleague fervently believes that layers of assurance, oversight and 'fuzzy' responsibility enacted by *layers of players* (LoPs) have created the perceived shortage. LoPs have been largely encouraged by tunnelling clients and their procurement *fashionistas* who believe that by doing so the project risks were being appropriately mitigated and managed. But in doing so this creates layers of sign-offs that are supposedly adding value and comfort for the owner, but the sum value of all the LoP signatures dilutes the whole purpose of ownership of responsibility, with each 'LoP' needing to be seen to add 'their' value and sense of purpose.

If we could rebuild a culture that mirrored the responsibilities, respect and expectations of what lies behind the intent of a signature we might just return to behaviours more in keeping with the traditional role of The Engineer. The added benefit of which might dispense with the layers of 'responsibility outsourcing'. Would the signee (knowing that the *'buck actually stopped'* with them) be more thorough and diligent in making sure that they did indeed understand what they were signing? Would they spend more time ensuring that they could honour and deliver the requirements and have dealt with the responsibilities of doing so?

To be clear many of the issues raised by my article have happened because our profession let it happen. Since the 1970s we stood by and watched the outsourcing of responsibilities that were inherently part of the Engineer's role. In doing so we created 'LoPs' and diluted the effectiveness of our duties and the overseeing role of The Engineer. The value of the Engineer's signature has in effect been outsourced and the *controlling mind* (which went with the value of the Engineer's signature) ebbs and flows in the complex tide of project processes and governance and LoPs.

Change in behaviours can't happen overnight. But gradually, signature by signature, we could as professionals force ourselves to consider the commitment that we make for what we sign off. And, most importantly, are we indeed competent to sign? Hesitate and let the pen hover over the dotted line or tick box the next time you are required to provide your signature in a professional capacity. Have you thought about why you signing? In signing you are knowingly, as professional, undertaking a commitment (or on behalf of an organisation) that you are knowledgeable of, and that you stand by what you pledge.

So value and respect your signature. By so doing you will improve the behaviours our industry, our own professional self-esteem and it will improve the value of and respect for The Engineer



**Above: Martin Knights**  
PHOTO COURTESY OF THE ROYAL ACADEMY OF ENGINEERING

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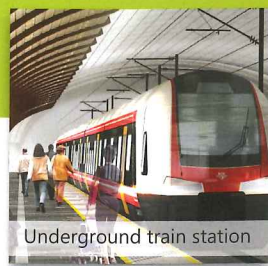
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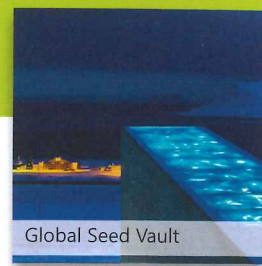
Worldwide there is a quest for urban space driven by the increasing urbanization.

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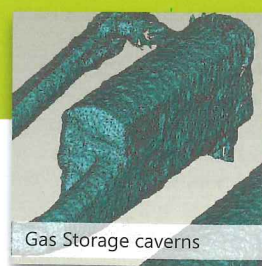
"Surface challenges – Underground solutions" is more than a slogan; for ITA-AITES and its members it is a challenge and commitment to contribute to sustainable development.



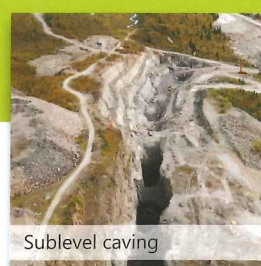
Underground train station



Global Seed Vault



Gas Storage caverns

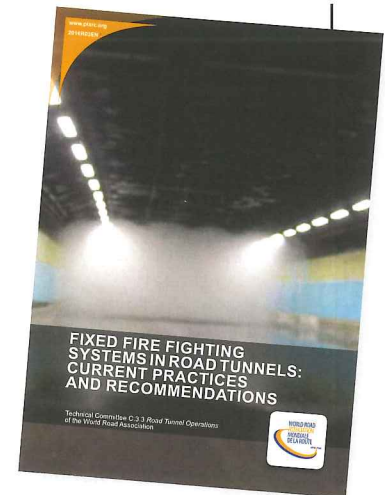


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# APPLICATION OF FIXED FIRE FIGHTING SYSTEMS IN ROAD TUNNELS



An examination of the 2015 technical report on fixed fire fighting systems (FFFS) in road tunnels. This article was edited in collaboration by the World Road Association working group for tunnel operations, led at that time by LBA's Les Fielding, which produced the document. The main authors were **Bruce Dandie** director at RRT Pty Ltd, Australia **Norris Harvey** practice leader: Fire & Life Safety, Hatch Mott MacDonald

### The Report

Technical report 2015 Fixed Fire Fighting Systems in Road Tunnels: Current Practices and Recommendations entirely replaces and updates the earlier report *Technical Report 2008 R07 "Road Tunnels: An Assessment of Fixed Fire Fighting Systems"*. The 2015 report summarises the World Road Association's views on Fixed Fire Fighting Systems (FFFS), and its recommendations pertaining to the applicability, selection and operation of such systems.

**T**HE TERM FFFS REFERS to a range of technologies that use water as the suppression agent, or water with an additive or some other extinguishing agent. These systems are installed as part of the tunnel infrastructure and require no additional elements to be added when called upon to fight fires. As such, these systems are part of the "fixed" installation, having been installed for the specific purpose of controlling a fire incident over a specific area and are activated automatically, semi-automatically, or manually from a remote location. FFFS are now recognised as one of a range of active technologies which, when appropriately designed, integrated, installed, operated and maintained can positively contribute to asset protection and life safety.

FFFS have the potential to reduce the rates of fire growth and spread, thereby assisting the safety of motorists and the emergency services during the self-rescue and assisted-rescue phases of a fire. Other potential benefits of FFFS relate to minimising fire growth rates and fire spread, thereby reducing the risks to tunnel assets from fire damage, and thereby to avoid

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or reduce the road network interruptions that may occur while a tunnel is being repaired following a fire incident. A systematic approach is recommended to support the decision as to whether such a system should be installed:

FFFS must be considered in the context of other critical safety systems such as ventilation. Rapid and accurate incident detection and FFFS response are essential components to achieve the best possible performance. The operational performance of FFFS can best be assessed through a system engineering approach, including appropriate regimes for maintenance, testing and training. Careful consideration must be made with respect to the effects of such systems on operational procedures and maintenance budgets.

FFFS have been reliably used in tunnels since the 1950s however their use remains the exception rather than the rule in road tunnels worldwide. While such systems reduce the rates of fire growth and spread, they also demand ongoing maintenance and operational integration to ensure they function in an optimal manner. Like all active life safety and asset tunnel protection systems a decision to use FFFS must be coupled

with a willingness and capacity to design, integrate, install, operate and maintain the system.

**TYPES AND FEATURES**

**Deluge systems**

Deluge systems are typified by a zoned water application, characterised by a significant proportion by volume of relatively large water droplets. The exact performance of these systems varies from tunnel to tunnel as their performance is usually specified as an application rate over a discrete section of tunnel, or as a delivered density application rate in mm/min or l/min/m<sup>2</sup>, and not on the basis of droplet size distribution.

**Water mist systems**

Water mist systems can be either low or high pressure, however, the pressures used are typically higher than that used for deluge systems. Water mist systems are typically used where the volume of water, spatial considerations, or weight restrictions, are issues. Mist systems are characterised by relatively fine water droplets, which assist cooling by the evaporative process. Systems are specified based on the volume of the tunnel in the application zone in l/min/m<sup>3</sup>.

**Common features and variances**

Both systems are characterised by:

- A water supply with sufficient reliability, quality, quantity and pressure for application at the required rate over the designed tunnel area;
- An activation valve (typically a section valve or a solenoid) that controls the flow of water to the distribution network and hence does not rely on localised fusible link sprinkler heads;
- A water distribution network between the activation valve and the spray nozzle;
- The ability to deliver a predefined volume of water over the designated fire zone for a predetermined period of time.

Water mist systems vary from deluge systems in that water mist systems typically:

- Use higher pressures than deluge systems;
- Use smaller diameter pipework than deluge systems;
- Uses less water volumes and flow rates for the same area of coverage;
- Use more specialised material and equipment such as for pumps, pipes and nozzles due to the higher

operating pressure, and the requirement to keep the fine spray nozzles clear of any particles that may occur in the pipe network and block the nozzle openings. The need to eliminate blockages may also require the addition of filtration systems.

**DECISION FACTORS AND DESIGN CONSIDERATIONS:**

When deciding whether or not to install any type of FFFS, the following must be examined:

- Compliance with local regulations and guidelines, including legal considerations;
- Global guidelines and safety standards;
- Life safety;
- Asset protection and the protection required to assure the availability of the transport link;
- Flexibility for additional traffic regimes such as dangerous goods vehicles;
- Fire-fighting response;
- The ability to adequately operate and maintain the system, including the roles, positions, and responsibilities of the stakeholders and training of operators;
- The installation capital cost and or life cycle cost, as well as the cost benefit from installing FFFS;
- System reliability and redundancy; and
- Sustainability, as this may also be a factor in the decision.

Once it has been determined to install the FFFS, the designer must establish a viable working design, and consider the following design issues in the process of developing the design of the FFFS:

- Design fire;
- Type of system;
- Water suppression characteristics (mist or deluge);
- Water supply including possible hydrant and or standpipe systems;
- Tunnel drainage;
- Space considerations;
- Fire detection/activation strategy;
- Environment;
- System integration;
- Interaction of FFFS with ventilation; and
- Other factors.

**RESEARCH AND ANALYSIS**

Various types of Fixed Fire Fighting Systems (FFFS) have been used in buildings for more than 150 years. These systems are well understood in the building industry and are required by many codes and standards for the protection of life and property. In road tunnels, this has not always been the case.

In 1999 when PIARC "Fire and Smoke Control in Road Tunnels" guidance was published; FFFS were not recommended and were not accepted in many parts of the world due to fears of creating adverse conditions in a road tunnel environment. While these fears have generally been proven to be groundless, and the benefits of FFFS have been validated by fire testing and operating experience, the installation of FFFS is still not considered to be appropriate for all road tunnels.

**FIRE TESTS**

In 1965 the tests carried out at Offenegg indicated that FFFS were not safe for use in road tunnels. These tests, together with other considerations believed to be valid at the time led to the following beliefs:

List of notable test programmes

Test programme	Year performed	Test facility location	Type of FFFS
Sweden T-Rex	2013	Runehamar, Norway	Deluge
SOLIT 2	2012	San Pedro de Anes, Spain	High pressure water mist
Singapore Test Programs [43]	2012	San Pedro de Anes, Spain	Deluge
M30, Madrid Test Program [46] [47]	2006	San Pedro de Anes, Spain	High pressure water mist
SOLIT 1	2006	San Pedro de Anes, Spain	High pressure water mist
A86, Paris Test Program [62]	2005	VSH, Switzerland	High pressure water mist
2nd Benelux Tests [45]	2001	Benelux Tunnel, The Netherlands	Deluge

- i. Water can cause explosion in petrol and other chemical substances if not combined with appropriate additives;
- ii. There is a risk that the fire is extinguished but flammable gases are still produced and may cause an explosion;
- iii. Vaporised steam can hurt people;
- iv. The efficiency of extinguishment is low for fires in vehicles;
- v. The smoke layer is cooled down and de-stratified, so that it may cover the whole tunnel leading to loss of life;
- vi. Maintenance can be costly;
- vii. Visibility is reduced.

For the next 40 years, other than Australia and Japan and specific tunnels in the USA, FFFS were typically not installed in road tunnels. Research and testing carried out since the Mont Blanc, St. Gotthard and Tauern Tunnel Fires between 1999 and 2001 has further considered the use and application of FFFS.

In the large number of tests carried out, no explosions have been caused by FFFS; flammable gases did not continue to be produced and hence no explosions occurred and vaporised steam was not generated in sufficient quantities to constitute a threat.

The tests did show that shielded fires were not entirely extinguished however thermal management is shown to be achieved; stratified smoke is de-stratified upon activation of the FFFS and visibility is reduced within the FFFS zone of application. Tests have shown that early activation of FFFS limits the fire heat release rate. Early fire control in practice, can be achieved by remotely operating the system before the arrival of the Fire Service.

**LESSONS FROM REAL LIFE INCIDENTS**

The objectives and benefits of FFFS have been illustrated by the Burnley Tunnel Fire of March 2008. During rush hour in Melbourne, Australia, a heavy goods vehicle swerved and impacted a vehicle in the adjacent lane. There was an immediate explosion and an ensuing fire. The activation of the deluge sprinkler system and ventilation system did not put the fire out, but it did minimise the spread of the fire and allowed time for the fire brigade to arrive at the scene of the incident. The injured people were a result of the accident and not the ensuing fire. There was no damage to the tunnel and traffic was able to use the tunnel shortly thereafter.

**CONCLUSION**

Fire events in tunnels continue to show the significant consequences of these types of events in a road tunnel environment to tunnel users, the tunnel infrastructure, as well as the impact to the wider road network on society. This has produced sustained pressure for further improvements to techniques and technologies to manage the risk and consequence of fires in tunnels. FFFS are a method that can deliver user safety and infrastructure protection; however,

Above: Figure 1, Some of the more influential test programmes

their use is not widespread for various economic, technical, political and social reasons. This report provides guidance on the decisions required before adopting FFFS and, if FFFS are to be adopted, provides guidance on the required design and implementation considerations.

Extensive testing has demonstrated that while FFFS have the ability to reduce the fire size and prevent the fire load reaching its full potential, high gas temperatures may still be reached that affect the structure or other infrastructure in the immediate vicinity of the fire. This has a direct link to choosing the correct design fire HRR for the design of FFFS to limit fire growth to, and the adoption of procedures to assure early activation of systems in the event of fire.

Where installed, maintained and operated effectively, FFFS have a positive impact on egress by extending the available evacuation time. This benefit applies to vehicles upstream in a longitudinally ventilated tunnel, and to both sides of a fire in a transversely ventilated tunnel. However, while the conditions downstream of a fire in a longitudinally ventilated tunnel are significantly improved, untenable conditions may still exist after activation of the FFFS.

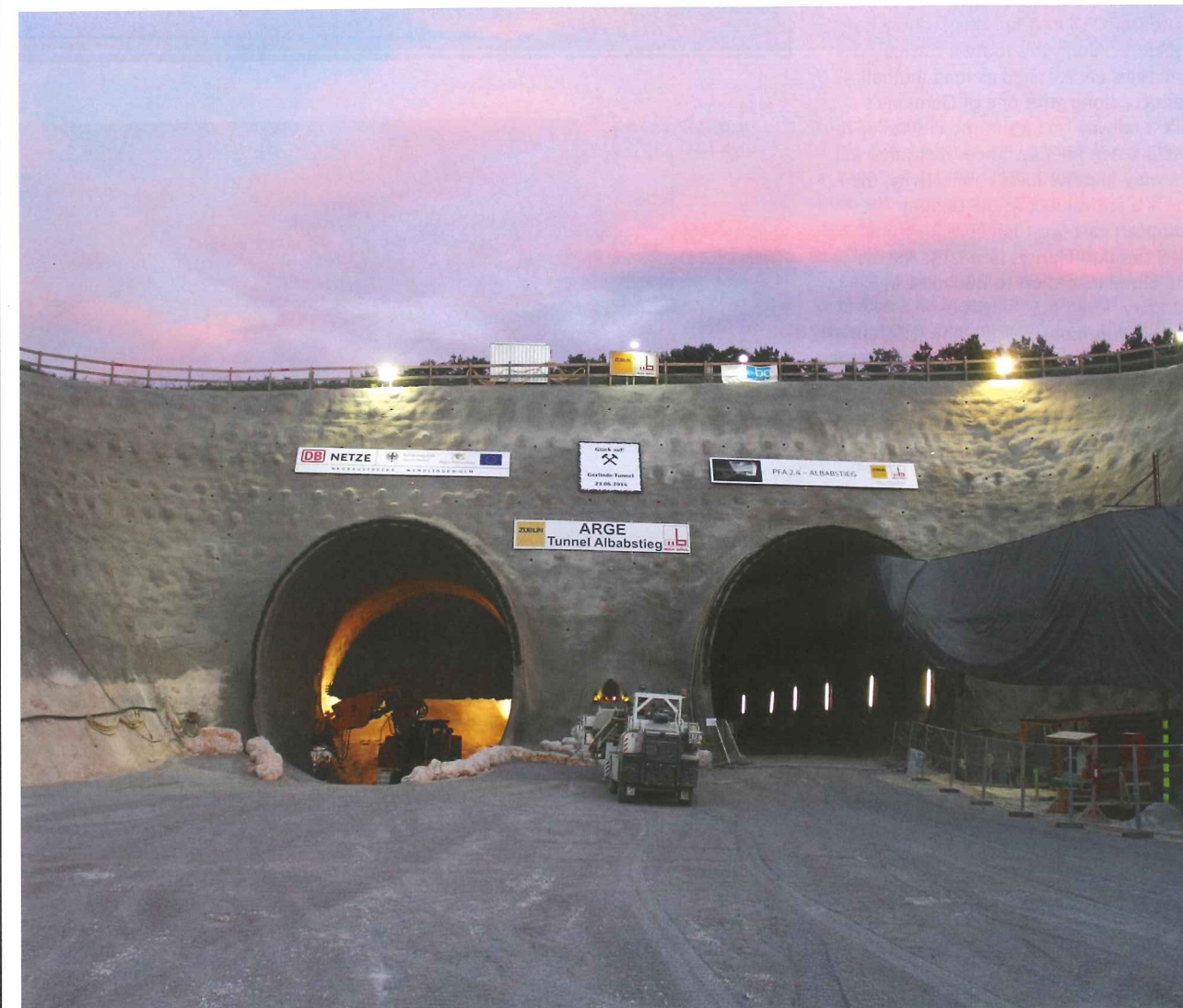
The length of tunnel roadway covered by FFFS is affected by the available water supply and the tunnel width. Operation of FFFS can reduce the visibility for drivers within the area of operation, however, most vehicles within the activated zone(s) should be stopped as a consequence of the fire event.

Nevertheless, procedures should be adopted to manage traffic and operate the tunnel systems without exposing motorists to additional hazards. This also means that FFFS should be reliable and the potential for false activation eliminated.

FFFS are now recognised as a proven active technology for the management of risks to both tunnel assets and tunnel users from fires

# ULM APPROACH TUNNEL

Excavation of Germany's Alabastieg tunnel was completed in December representing a major milestone in the creation of a new high speed rail line to Stuttgart



**Bernadette Ballantyne**  
Bernadette is an engineer and freelance technical journalist

**Above: Tunnel portals on the Alabastieg descent tunnel**  
ALL IMAGES © ARGE TUNNEL ALBABSTIEG

**B**UILDING THE ALBABSTIEG TUNNEL is a major project on its own. Over 4.5 years the contracting team joint venture of Züblin and Max Bögl will drill and blast 12km of a new single tube tunnel for client Deutsche Bahn AG that will take new high speed trains beneath the network of roads that lead into the city

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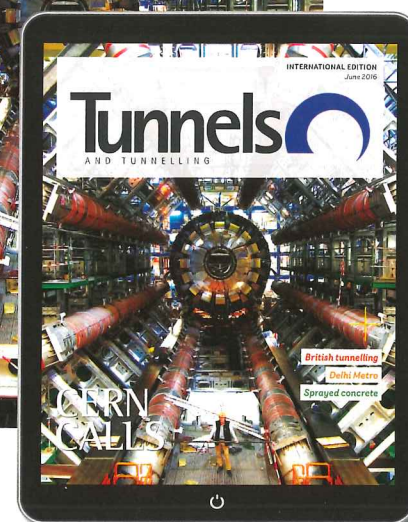
FP McCann offers a complete range of Tunnel and Shaft solutions including our Smoothbore Shafts from 2.44m - 25m diameter, bespoke cover slabs made to specification, full range of Jacking Pipes from DN450 - DN2400 and Caisson Rings from DN2100 - DN4000. All FP McCann products are Design Chemical Class 4 (DC4) compliant.

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| <p><b>April</b><br/>Regional focus: Europe<br/>Tech: Precast</p> <p><b>May</b><br/>Regional focus: The Americas<br/>Tech: Waterproofing</p> <p><b>June - WTC Norway distribution</b><br/>Regional focus: Europe<br/>Tech: Asset Protection</p> <p><b>July</b><br/>Regional focus: Asia<br/>Tech: Logistics</p> <p><b>August</b><br/>Regional focus: Middle East and Africa<br/>Tech: Health and Safety</p> | <p><b>September</b><br/>Regional focus: The Americas<br/>Tech: SCL / NATM</p> <p><b>October - Expo Tunnel distribution</b><br/>Regional focus: Europe<br/>Tech: Fibres</p> <p><b>November - TBM DiGs China distribution</b><br/>Regional focus: Asia<br/>Tech: Drill and Blast</p> <p><b>December - STUVA distribution</b><br/>Regional focus: The Americas<br/>Tech: Risk and Insurance</p> |
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of Ulm. "We are building two single track tubes each around 6km long. At the north end there is a small village called Dornstadt and on the south end it goes down to the main railway station of Ulm," explains Matthias Abele, the project manager for Züblin.

The two 5.94km tunnels are part of a larger scheme to build a 59.6km new high-speed rail line between Wendlingen (Neckar) close to Stuttgart and Ulm to the southeast.

A total of nine tunnels are required accounting for 30.4km of the new and improved public transport connection, which will increase train speeds along the route from 70km/h in some sections to 250km/h. Along this route a further 40 structures are required as road and rail viaducts along with one of Germany's tallest railway bridges in the Fils Valley in Mühlhausen im Täle. These measures will not only improve local connectivity, the line is a critical link in the Central European east-west rail corridor from Paris through France, Germany, Austria and Slovakia and on to Budapest in Hungary.

This enormous EUR 3.26bn (USD 3.46bn) project sits alongside the even larger EUR 6.53bn (USD 6.92bn) Stuttgart 21 project, which is transforming the city's rail network. At the heart of this is the reconstruction of the central railway station, which will no longer be a traditional terminus style station where trains must enter and leave along the same line leading to congestion at busy times. Instead Stuttgart will have a modern drive through arrangement where trains may stop or pass by the station, which also has waiting areas and allows operators the flexibility to manage more



Left: Tunnel formwork rigs were supplied by Baystag



Top: Western view of Ulm with tunnel location overlaid

Above: The tunnel portion in question takes trains in to the city © DB P-S-U

trains effectively. As well as the station upgrade a new central railway ring will be constructed to allow more trains to connect into the city including a new station for Stuttgart Airport allowing it to connect in to the regional and long distance rail system.

Abele explains that the Albabstieg contract started in August 2013, with work beginning on site in December 2013. "We started with the excavation in April 2014 and actually we ended the excavation this week with the breakthrough in Ulm," he says (talking to T&T in early December).

The location of the tunnel in the low-lying mountain range of the Swabian Alps naturally determined the need for drill and blast tunnelling.

"There are mostly geological formations of massive limestone (about 60 or 70 per cent) and in between is the possibility of cavities (voids) and also there is a second geological formation, which is a sedimentary rock, which in German is called Süßwassermolasse," explains Abele.

To conquer this, the contractor used EUR 32M (USD 33.9M) of tunnelling equipment including 10 Sandvik DT 1130i drilling jumbos each with two drilling-arms and one lifting platform; eight CAT 328 excavators, eight Volvo L 150 tunnel loaders and 18 Volvo A 30F dump trucks for rock removal.

"Around 30 per cent of the rock is reused in this project and the other 70 per cent is taken away and used as fill in different places," says Abele.

The drilling strategy required using the rigs in three locations in each tunnel. Four began at the north of the bore at Dornstadt (two in each tube), two excavated the mid-section and two more pairs worked south from the middle of the tunnels to Ulm. "In 24 hours we moved about 4.5m in one direction. For drill and



Above: Rolling formwork rig



Left: Waterproofing sheets visible in the tunnel

blast we are working 24 hours, seven days per week. A complete cycle takes four to five hours. With excavation and transport and bringing out the shotcrete into the tunnel we do four times in one day," says Abele explaining that the maximum rate was 6.5m [double] in 24 hours.

As is typical with drill and blast the team used the rig to drill the holes, which were then loaded with explosives. The team then maintained a 150-200m distance back from the face as the charges were exploded. The removal of this rock then took another two hours. Following on from this shotcrete is minimally sprayed at a 200mm thickness.

Where the ground contains softer rock steel mesh reinforcement is required within the shotcrete along with steel ribs every 1.5m and the shotcrete increases to a thickness of 350mm. "The rock is difficult as it goes from very hard to soft and is at both extremes in the project," says Abele.

"For very hard rock you have to drill 140 holes and at the other extreme you only use a tunnel excavator or around 40 holes with drill and blast."

Once the second layer of shotcrete has been sprayed the team can immediately move on to the next advance. "The shotcrete quality means we have no time to wait and can start the drilling machine for the next 1.5m," says Abele.

For the whole project team, which had a peak labour force of 450 people (drill and blast, inner lining concrete shell and groundwork outside the tunnel), the most challenging aspect of the bore was the passage beneath buildings in Ulm. "There were big houses four to five floors built in 1940s or 1950s, which were very difficult to excavate under," says Abele explaining that the minimum cover here was just 11m. "We had to excavate very carefully," he says explaining that the advance rate was slowed

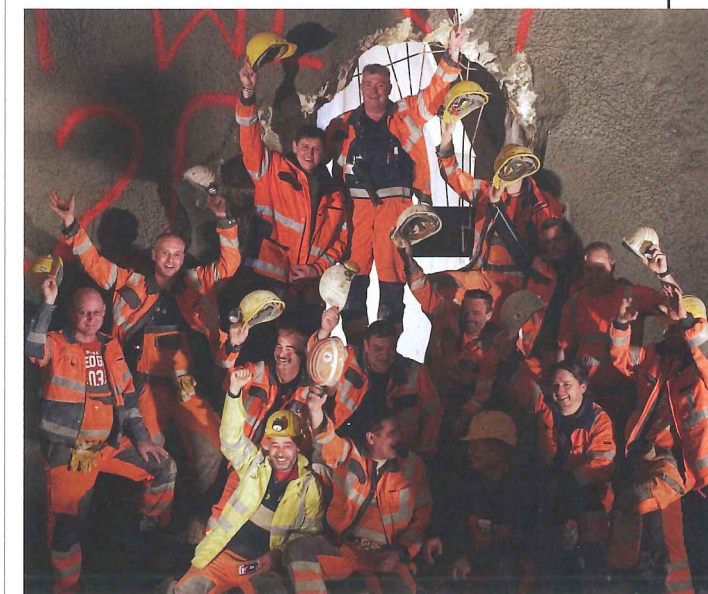
to just 0.5m in 24 hours. As for the inner lining work this began in mid 2015 using large formwork rigs from sub-contractor Baystag to place the cast-in-situ concrete.

"We are using two formwork machines in each tunnel for the cast-in-place concrete. The inner lining is about 400mm to a maximum 500mm thick. The reinforcement requirement depends on the structural engineering on average 80 to 110 kg/m<sup>3</sup>," he says.

Waterproof liner sheets are sealing the tunnel using 2mm thick membranes manufactured by Germany's Naue, installed on site by Strabag's waterproofing department.

Now that construction has moved into the lining and fit out phase the number of people on site has fallen to 200 and by mid-2018 the tunnel will be complete, providing a vital 6km link on the new Wendlingen to Ulm high-speed rail

Below: Crews celebrate daylight on the project



# ISTANBUL'S INFRASTRUCTURE

Istanbul urgently needs solutions for fresh water and wastewater management as well as for urban transportation. Technical journalist **Roland Herr** presents two projects, a wastewater and a Metro tunnel, where TBMs from the newly rebranded Canadian-Chinese Lovsuns Tunneling Canada are deployed to bore much anticipated tunnels.

## Roland Herr

Roland is a freelance technical journalist who splits his time between several companies



Connecting the two continents Asia and Europe, the Turkish Metropolis Istanbul is one of the biggest Cities of the World

**W**ITH MORE THAN 14 million residents Istanbul is one of the largest cities worldwide, the only one spanning the two continents: Asia and Europe, and bordering the Black Sea and the Mediterranean Sea. For that reason, it's not surprising that a megacity like the Turkish Metropolitan area is in need of many tunnel solutions. Especially in the field of infrastructure the government is investing huge sums to improve fresh- and wastewater management, traffic and public transport.

According to European Union reports, Turkey is one of the fastest growing markets for wastewater solutions. The Turkish Wastewater Treatment Action Plan 2023 provides that the number of treatment plants will increase from around 650 in 2015 to more than 2150 in 2023. The expansion and conjunction of the existing wastewater tunnel system is arguably one of the most important topics officials are facing. One of these projects is the bypass tunnel for the wastewater line in Istanbul's Zeytinburnu district.

### THE ZEYTINBURNU TUNNEL

The 3.91m-diameter EPBM from Lovsuns/LNSS finished its excavation some months ago--the first 2km-long bypass in Zeytinburnu to discharge the existing system. The aim of the Ayvali-2 Tunnel is to increase drainage wastewater capacity of the existing lines of Bagcilar, Esenler, Gungoren and Zeytinburnu. The Tunnel will carry the wastewater of these main hubs of Istanbul to the Yeni Water Treatment Facility.

### FIRST BREAKTHROUGH IN SEPTEMBER 2016

The Turkish construction company Eferay Yapi Ticaret together with the Canadian-Chinese Lovsuns Tunneling Canada celebrated the first breakthrough of the 3.91m-diameter single shield EPBM in September 2016. The TBM launched from a



overburden was between 8m and 40m, however in the last 150m before reaching the target shaft, the tunnel passed just 6m below the foundations of the nearby housing areas.

After the first breakthrough in Zeytinburnu, the TBM was disassembled and transported to the second launch shaft in Ayazaga, also situated on the European Side of Istanbul. The second drive will be 7.29km long. It is also a discharge tunnel, between the existing wastewater tunnels of Kemberburgaz and Ambarli. Here the ground will be limestone and sandstone. The drive will be divided into two sections with an intermediate shaft after 4km. All shafts have a diameter of 9m. Originally it was planned to use more shafts, but due to the small diameter of the TBM this was not necessary. The drive is expected to start early this year. The inner lining will be constructed with concrete 5+1 segments, which are built in a segment factory 20 to 25km away and delivered to the job site as needed.

**MUCK REMOVAL**

For muck transport a locomotive is used in the tunnels. The muck is then transported by trucks to an old mining area in the northern part of Istanbul. This is the only place to deliver the muck for the whole European Side of Istanbul and especially in winter it is very difficult for transportation.

**TBM DATA**

The TBM is an EPB designed as a mixed face (soft ground and rock) single shield. The shield diameter is 3.91m with a cutting diameter of 3.94m. The maximum pressure is 3 bar. The machine is designed for a minimum curvature radius of 400m and a maximum advance rate of 6m/h. The whole TBM is 89m-long with a shield length of 8m and a back-up length of 80m, altogether approximately 650t heavy.

The shield is equipped with 20 single, two twin and one quad replaceable disc cutters for the rock cutting mode and 28 ripper teeth, 40 scraper tools and two oil pressurized wear indicator ripper teeth for the soft ground configuration. The hydraulic main drive contains motors that deliver a total power of 524kW to the cutting head. Maximum torque of the cutting head is

*Above: Breakthrough of the 3.91m diameter EPB-TBM from Lovsuns for a wastewater tunnel in Istanbul in September 2016*

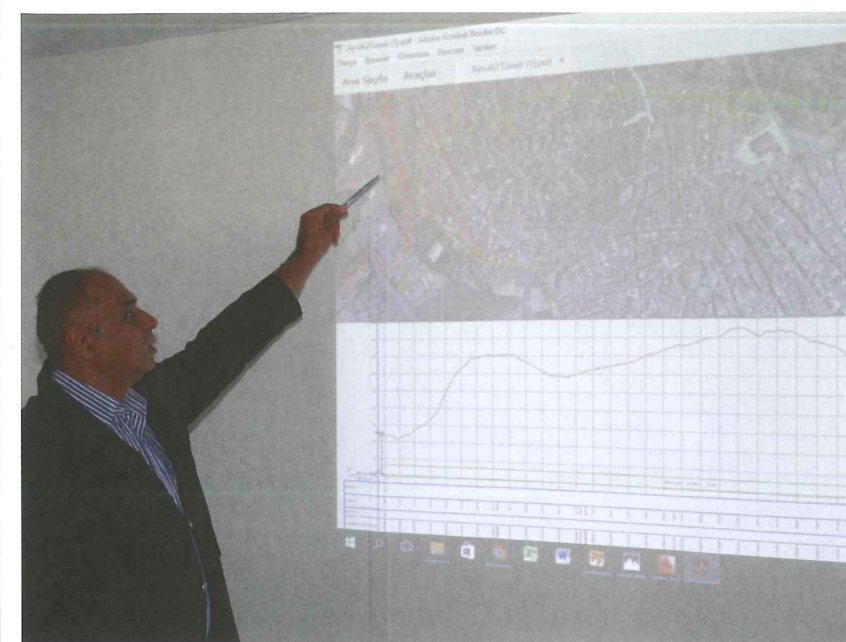
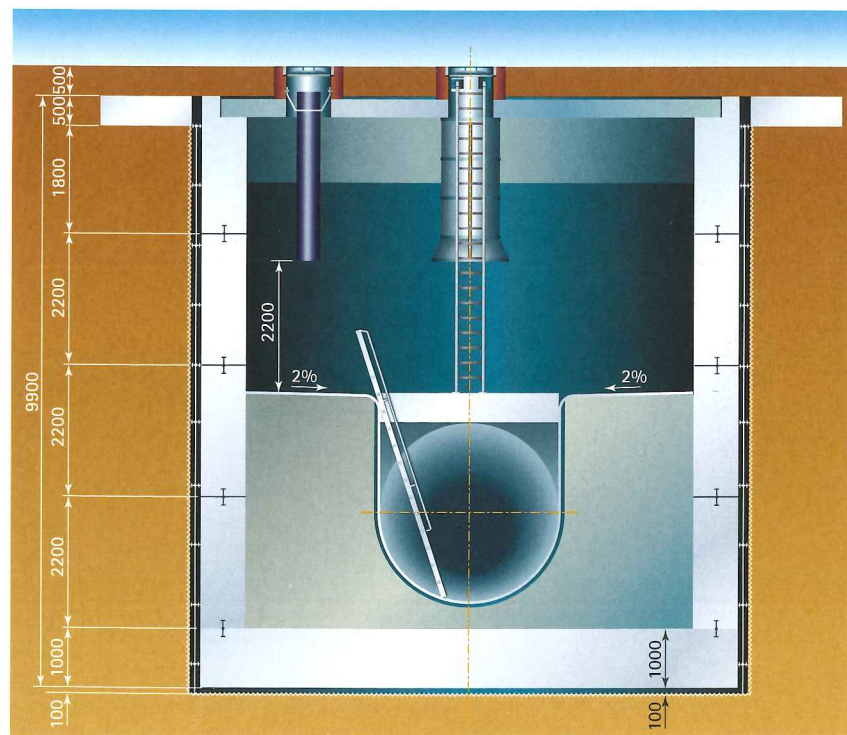
21m-deep shaft and broke through into a 12m-deep target shaft after around nine months boring. Normally the drive could be expected to be much shorter, but due to problems with muck transportation during the winter, processing on the job site took more time than expected. The TBM for the wastewater tunnel was one of the first contracts for the Lovsuns Company (formerly Lovat and now an overseas subsidiary company of Liaoning Censcience Industry [LNSS]).

Project manager Muammer Cinar explains the situation for the TBM works: "The overall project includes 10km of tunnels, divided into an initial 2km and a second 8km section. After one month of assembly, the TBM started to drill the first section in the middle of December 2015."

**GEOLOGY**

The geology found in the area showed sandstone, siltstone, clay and soil with high groundwater inflows. During the last 150m drive, the TBM headed under a highly-populated area. Here grouting to stabilise the ground helped to prevent higher water ingress and simultaneously secured the stability of the buildings on the surface. Due to these measurements the advance of the tunnel was very good. Thanks to the crew and the machine the best shift showed an advance of 15.6m, the best daily advance was 31.2m and in the best week 153m of the tunnel was driven. The best monthly advance occurred in April 2016 with 512m. The usual

*Right: Cross section of the 12m deep target shaft*



*Above: Project manager Muammer Cinar explains at the longitudinal section of the wastewater tunnel the details of the tunnelling drive*

1,883kNm with a speed of 2.66 rpm. The operator station is specially equipped with a programmable logic controller (PLC), which controls all machine functions and records the data. Integrated in the PLC is a logging system recording information about the performance of cutterhead, screw conveyor, main drive, grout injection and other systems.

Additionally the TBM has an automatic guidance system and ground conditioning System with a foam injection rate of 60 m<sup>3</sup>/h (1,000 l/min). The grout injection system delivers two different components (component A with 12 m<sup>3</sup>/h and component B with 1.2m<sup>3</sup>/h) with 16 bar maximum pressure. The ventilation system has a capacity of 150m<sup>3</sup>/min.

*Left: Rolling stock was used to remove the muck*



**A REFURBISHED MACHINE FOR THE ISTANBUL METRO**

In 2017, and solely for the extension of the metro system a total of 24 TBMs will be ordered for job sites in Istanbul. For the extension of the Metro Line M7 Lovsuns delivered a CAT 6.12m EPB that was previously used in the Toronto Metro Project in 2010, refurbished in Toronto and skinned up to 6.5m. The TBM started the 4km drive end of 2016 in the highly populated Kabatas area on the European side of Istanbul to bore two sections.

The daily traffic in the metropolitan region of Istanbul is a huge problem. The Istanbul Metro began services in 1989 to redistribute the commuter traffic from the streets to underground transportation. Four Metro Lines on the European and, since 2016, two on the Asian side of Istanbul are used by more than one million commuters, with rising numbers. The Istanbul Metro system consists of nearly 90 stations (more than 65 underground) and is at the moment around 150km long.

Five more lines are planned to be built or have construction ongoing, which will almost double the number of stations and increase the coverage for Istanbul's commuters:

- M3: Kirazli - Bakirköy-IDO (planned to open in 2019)
- M4: from Tavsantepe (formerly known as Kaynarca) to Istanbul-Sabiha Gökçen International Airport (7.4km; construction finish is planned for 2018)
- M7: Mecidiyeköy - Mahmutbey; construction began in Feb 2014 and was later extended from Mecidiyeköy via Fulya, Yıldız (old: Darphane on map) and Besiktas to Kabatas, totalling around 24.5km with 19 stations (due to open in 2018)
- M8: Cross-city Line on the Asian side from Bostanci to Dudullu (14.3km, start of operation is planned for 2019)
- M9: Tangential Line through western suburbs from Ikitelli Sanayi to Ataköy (13km, planned to be finished in 2019)

All lines on the metro system are operated by Metro Istanbul.

**METRO M7, FULYA TO KABATAS**

As mentioned, the Istanbul Metro is currently undergoing a massive extension with more than 70 stations and more than 330km of route under construction. Most of this will be constructed on completely new lines and some will be added to the existing routes. The Metro M7 is the largest project, started in 2014, and is to be executed in two stages and is

planned to start service in 2018. The new route includes 19 stations from Mahmutbey in the Northwest to Kabatas in the Southeast, an important ferry hub for commuters between Asia and Europe.

**LOGISTICAL CHALLENGES**

“The very narrow urban environment is challenging the job site for the tunnel works extremely”, explains tunnel manager Yigit Gencay from Alsim/Alarko. “We started to prepare the 81m-wide and 105m-long job site in January 2016 by securing the surrounding mountainous residential zone with earth piling.” Originally the Metro line should end in Mecidiyeköy, but then plans changed and the Metro was extended to Kabatas with four more stations. The original plan was to build only a launch shaft and a parking house in Fulya, but then changed to a Metro station due to the high population in this district. The civil works were given to two different contractors and Alarko won the contract for the extension line, the construction of the station and all electromechanical works.

Two shafts are situated at the Fulya job site. One is the launch shaft for the TBM to drive to Kabatas with return in a second tube back to Fulya. The shaft is 33m deep with a 12m diameter. The 4.5km tunnel will go from Fulya via Yıldiz and the very popular Besiktas area to the final station, Kabatas, directly at the ferry port. From the second shaft the tunnel heads in NATM to Mecidiyeköy. Underground the two shafts at the Fulya job site will be connected to the Metro station platform, which will be 240m long underground, 80m long on the surface.

Using the launch shafts for the TBM and the NATM tunnels, the underground station was built first. Then, from the wall of the station in the direction of Kabatas, a 15m-long Pilot Tunnel was drilled and a thrust frame was built for the TBM. After that, the 110m-long TBM with back-up was assembled in the station to start drilling in the Pilot Tunnel in EPM mode as soon as possible. At Yıldiz and Besiktas station, first of all, the stations will be built and then the TBM driven through the stations. Once it reaches the final station, Kabatas, the Lovsuns TBM will be disassembled and used for further projects of Alarko.

**GROUND CONDITIONS FOR EPB**

“Our mixed TBM serves perfect the counter balance between ground conditions and ground water with the cutting shield”, explains Gencay. In the Fulya area there is only some ground water in sand- and mudstone expected.



**Top:** The job site for the Fulya station of Metro M7 is situated in a highly populated area

**Above:** Istanbul Metro M7 alignment (pink) from Mahmutbey to Kabatas is with nearly 25km the longest extension

Towards Besiktas this includes Aluvium and Clay zones, further to Kabatas sea water may appear due to the very close Bosphorus. The TBM is designed to operate under 4 bars of pressure. The tunnel alignment is planned to be 33m deep in Fulya, 80m in Yıldiz, 20m in Besiktas and finally 40m in Kabatas. The tunnel slope from Fulya to Kabatas is graded 4.5 per cent downwards.

Especially in the Besiktas and Kabatas areas a water pressure of 2.5 bar with very fast changing ground conditions are expected. For the client and the contractor design and TBM choice was very important—that they have a lot of different options to react on the different ground conditions. For that reason the TBM is capable to use polymer pumping equipment and also pressurised bentonite in the cutting chamber with additives, foam and air. If there is a loss of pressure caused by critical ground conditions two pressurised and one electrical bentonite tank can be used to stabilise the ground.

To fill the gap between the ground and the outside of the lining, grouting is supposed to be done as quickly as possible. The TBM shows a two component grouting system:



- 1) a grout mixture made of cement, bentonite, water, a filler like fly ash, retarder or stabiliser (24-hour reaction time) and
- 2) a sodium silicate (accelerator for grouting), which speeds the stabilising of the grout mixture as quickly as possible

**Top:** Tunnel manager Yigit Gencay explains the EPB Shield from Lovsuns

To prevent settlements due to the difficult ground conditions and to protect the historical as well as the residential buildings, drilling and installing the segments must be done more or less simultaneously. But with the grout mixture, which needs 10 to 15 seconds of gel time to become stable, it is much easier.

The grouting pressure will be 0.2 bar more than the ground pressure. To inject the grout there are eight grout lines in total, but only four lines will be used at the same time. To make sure that the working area is safe, at the outer ring are three brushes installed containing greas.

The TBM is also designed to carry out probe drilling. On one hand it is possible to know more about the ground in front of



**left:** Launch shaft with crane for muck transport

the shield, but on the other, if the ground is collapsing or very fractured, it is easier to arrange an umbrella shield with 12 angled boreholes.

The contractor also tried to stay on the safe side by ordering a TBM that is built with a very durable steel quality. It may require longer stops due to repair works in the cutting chamber. Another important feature for the contractor was the double articulated shield.

**REFUGE CHAMBER**

A refuge chamber has been included to secure 10 persons for 24 hours in case of a disaster. Altogether 25 people work in one shift in- and outside the tunnel (13 to 15 people in the tunnel). The weekly personal plan is to work in two shifts each 10 hours for six days the first and seven days the second week.

**LOGISTICS**

The logistical problems for a job site in this overcrowded, highly-populated city are huge. Everything needs to be delivered on time or directly transported to an outside storage area. The logistic center on the Fulya job site is very small. The muck will be transported in the tunnel with rolling stock and muck cars to the shaft, taken with a crane from shaft ground to surface and dumped in a 20.5m-long, 35m-wide and 4m-high pool and also continuously cleared. Transportation by truck is not easy and needs to be adjusted without break.

Every day around 60 dumpers with 40t loading capacity leave the job site in direction to the dumping station around 25km away.

The segments – enough to build 15 to 20 rings every day – reach the job site from the segmental production plant which is 25km away, and also just in time due to a very limited storage capacity.

**CONSTRUCTION PROGRESS**

The in the middle of September 2016 assembly of the TBM started and in mid October 2016 the first ring was built. The total construction time for the tunnel with the Lovsuns EPB TBM only in the direction from Fulya to Kabatas is planned with 12 to 13 months.

After the start of railworks, electromechanical and signalling works, the interior construction of the station will be executed.

The distance between both tubes is around 32m and becomes closer as closer the tunnels reach the station.

The second tube from Kabatas to Fulya starts around six months later due to archeological examinations in the Kabatas and Besiktas area

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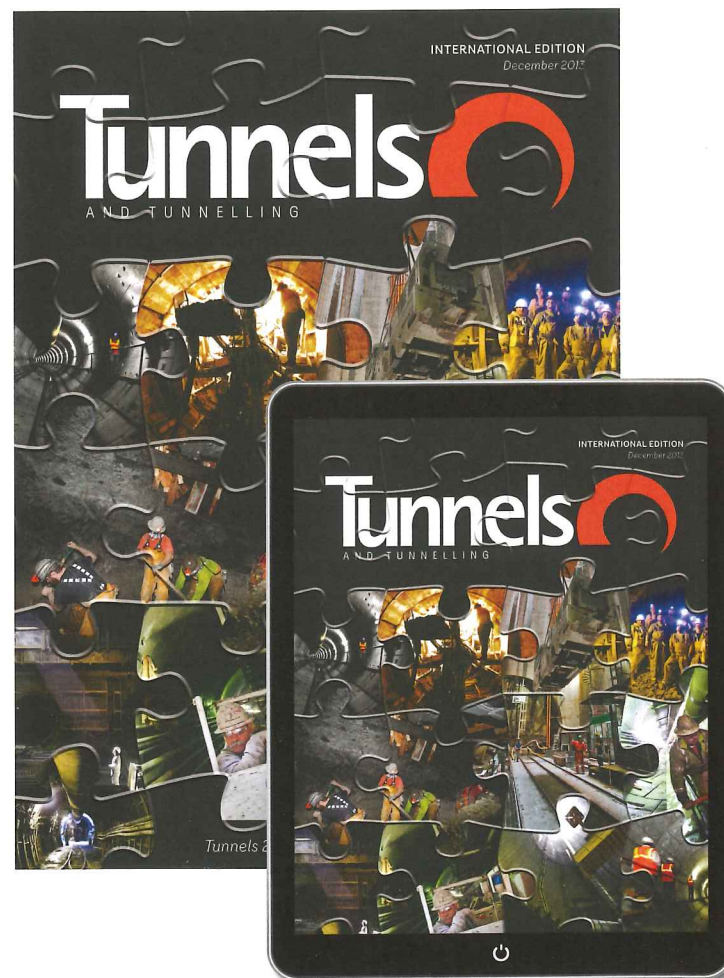
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## ASSET PROTECTION

Asset protection and tunnel lining systems were two of the themes underpinning a seminar hosted by steel fibre reinforcement specialist Bekaert Maccaferri last November. **Sally Spencer** reports

Below: Fibre reinforcement in concrete

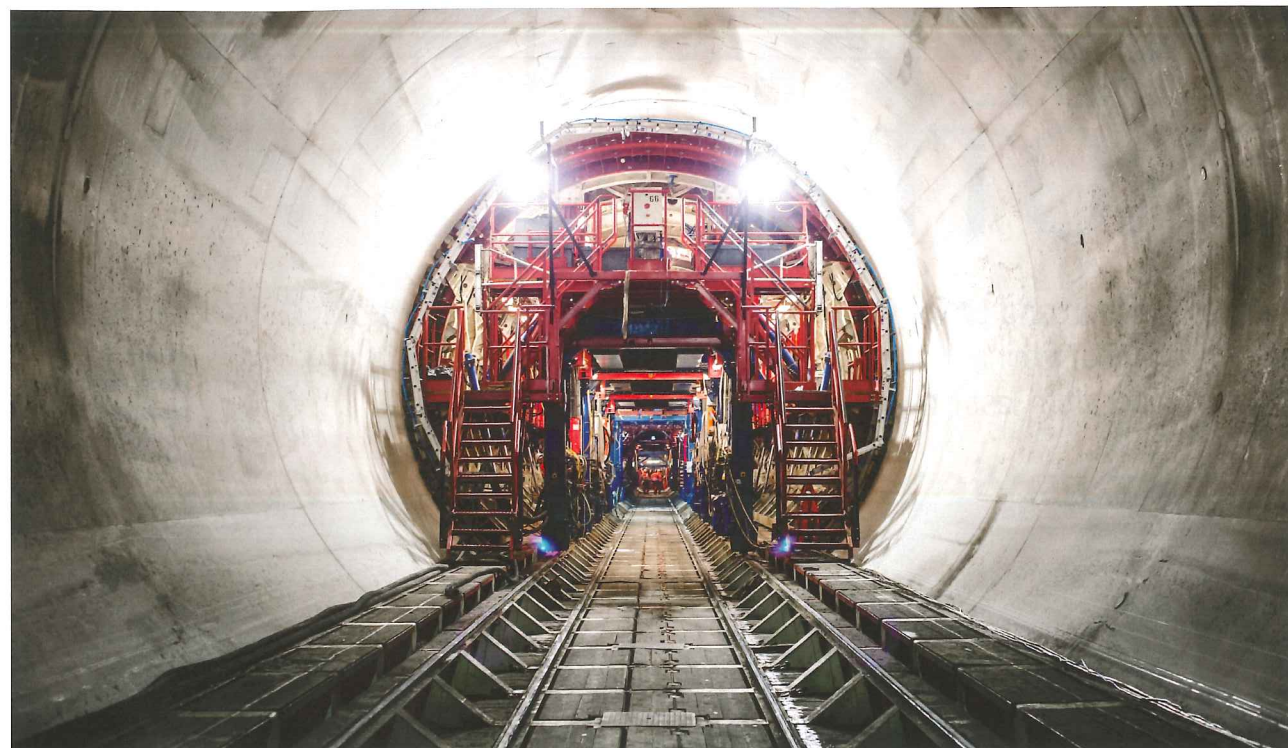


**T**HE UNDERGROUND SOLUTIONS SEMINAR at London's Institute of Civil Engineers kicked off with a lively presentation by Colin Eddie, managing director at UnPS. He looked at innovation over the last 20 years – including much brought to market by UnPS – current state-of-

**Sally Spencer**

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





**Above: The Lee Tunnel project in London, UK**

the-art techniques and technology and also at new materials and construction methods on the horizon.

Eddie said that the tunnelling sector was well placed to help achieve some global sustainable development goals, including gender equality; clean water and sanitation; industry innovation and infrastructure; sustainable cities and communities; responsible consumption and production; and climate action. He added that these goals were all the more critical as pressure increased on infrastructure and on society generally.

"The global trend is towards increased urbanisation in developing countries," said Eddie, adding that the world population is predicted to rise from 7.3 billion (in 2015) to nearly 10 billion by 2030.

"This creates cities with insufficient shelter and insufficient infrastructure and services."

Overcrowded transportation systems, inadequate water supplies and sanitation and increasing pollution were all potential results of urbanisation, he said.

As 'explosive' urbanisation continued, Eddie said the scale of tunnelling projects was also increasing and the global underground market value is currently close to USD 2tr (the UK's current underground market value is USD 60bn). But, he said, infrastructure costs are too high – particularly in the UK and current technologies are "literally stone age, scratching the ground".

#### TECHNOLOGICAL PROGRESS

Eddie recapped on a similar presentation he gave 10 years ago, touching on technology advances that had varying degrees of success in being brought to market.

Of these he mentioned the "truly remarkable" UltraShell lining, formed from a passive smart self-healing engineered cement composite, and the concept of using microwaves to break through rocks.

"How close are we to this?" he asked, adding that improved cutting tools could cause a paradigm shift in tunnelling.

Significant research, including by TBM manufacturers, is going on the field of microwave, water jet and laser cutting. Eddie quoted Anglo American mining group as saying it believed it would be cutting rock with laser tools in the next 10 years.

Eddie also looked at the concept of sustainable high-speed travel. The Swissmetro tunnel was being discussed 10 years ago, he said, but the futuristic project using vactrain technology went into liquidation in 2009 due to lack of support.

Nuclear-powered TBMs also came under the spotlight, with Eddie saying that Rolls Royce believes that portable nuclear reactors are 10 years from market.

"The US invested in research at the Los Alamos Scientific Laboratory of the University of California 10 years ago. A lot of people probably ridiculed it at the time but the science is upon us to make this work. The US Department of Energy was developing SSTAR [small, sealed, transportable, autonomous reactor], a portable reactor that has an operational life of 30 years without refuelling. Military and civil marine vessels are powered by nuclear energy, so why not TBMs?"

Eddie said other developments were on the closer horizon, including in the area of small freight delivery tunnel systems.

"Cities like London are crying out for more efficient freight delivery systems," he said, adding that UnPS is working with MoleSolutions and Arup to bring the first freight capsule tunnel to Southampton.

The Hyperloop concept also came up for discussion and Eddie is adamant the technology will be realised.



**Above: RamArch is a system developed for Network Rail by Innovative Support Systems**

"In May 2016 the French railways SNCF invested EUR 80M (USD 85M) into a 700mph (1,100kph) intercity super tube train which could make HS2 obsolete before it is built," said Eddie. "Arup is all over it because they know it can work."

Hyperloop has also signed a deal to link Dubai with Abu Dhabi, reducing the travel time from an hour to just 12 minutes. "This is real," said Eddie. "It's going to happen."

Eddie also looked at the benefits of extruded linings using a high-performance fibre reinforced material, which he said had the potential to revolutionise high speed tunnelling.

"Industry based R&D programmes are required to eliminate current problems but, again, this will happen," he said.

#### THE RIGHT FIBRES

Steel fibre reinforcement is moving on from something that simply improves the concrete and towards improving the rebar – it's not just about durability but is now adding a structural dimension.

This was covered by two Bekaert speakers. Benoit de Rivaz presented the company's latest steel fibre – Dramix 5D – while Hendrik Thooft introduced the eyeD System, which is the company's new online measuring device for Dramix.

De Rivaz made the point that reinforcement fibres came in all shapes, sizes and materials and that there was no good or bad product but that it was important to get "the right product for the right use".

He added that while the development from Dramix 3D to 4D was evolution, the development of the 5D fibre was more "revolution" because of the different way it works. "It opens up new opportunities in structural requirements," he said.

Dramix 5D fibres were used in the Lee Tunnel in Beckton, London. The project included five shafts connected by a 7m-diameter, 7km-long tunnel. The Dramix 5D steel fibre reinforced concrete (SFRC) for the slip-formed tunnel lining took 18 months to develop.

The five shafts were also designed and constructed using an innovative slip-formed type of shaft construction, which also incorporated SFRC. This substantially reduced the quantity of structural reinforcement, thus enabling a faster and safer construction process.

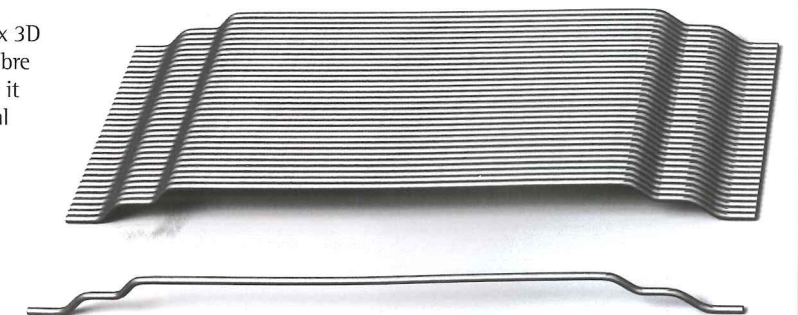
SFRC may have been around for decades but it is still a new concept for some designers "and it freaks them out", said Hendrik Thooft.

"There is caution among some contractors and consultants because they need reassurance that the fibres are really there and that they are distributed properly."

This quality assurance could be provided by Bekaert's new eyeD System, which has been brought to market and is already in use in Europe.

The eyeD device is a real-time measuring tool that analyses the homogeneity (not the number) of the

**Below: The Dramix 5D fibre developed by Bekaert**



steel fibres in the concrete mix as it flows through the chute of the concrete mixer. That data then transmits via 3G, 4G or WiFi to a tablet or smartphone for real-time monitoring and also to a central server.

"The eyeD weighs 25kg and can be operated by one person," said Thooft. "It is easy to operate and attaches simply to the chute of the concrete mixer with hooking cables – it is compatible with most chutes on the market. It is battery powered and has about eight hours of battery operating life."

Technical advantages include continuous measurement of the complete batch of concrete; immediate access to data, enabling speedy corrective action as required; full traceability of the measured data; elimination of "human error"; cloud storage of data; privacy of measured data; full reporting on compliance with the job site specification; and certainty that the reinforcement is in the right place.

Thooft said certain fibres could incorporate RFID markers, thus providing "full traceability" and that while at present the eyeD just measured the ambient temperature, they could add the functionality to measure the temperature of the concrete.

Five eyeD devices are currently available to rent and will be operated exclusively by quality control companies who will be trained in its use by Bekaert. It is only compatible with Dramix fibres.

"If other fibres are used it will work but it won't store the data on the server," said Thooft, adding, "the eyeD is not a gimmick – it should be part of the whole quality control plan".

### SEALING AND PROTECTION

Vincent van de Vrie of Trelleborg Engineered Products presented a paper on polymer solutions for tunnels, which outlined the company's sealing and



Left: RamArch system in the factory



Above: Work to install RamArch at the Whiteball Tunnel

vibration-damping products for bore and immersed tunnels.

These include the Gina Profile, which is designed for immersed tunnels and has a 120-year life and the Omega Seal, which is the company's primary product.

Van de Vrie also outlined the design possibilities of the company's Waterstop, which ensures a water-tight seal between construction joints, and four types of tunnel segment gaskets – glue in, slotted hydrophilic, co-extruded hydrophilic and cast-in.

Michael Uebigau from Agru spoke on the merits of concrete protection liners, which provide separation against water seepage and pressing ground water. He highlighted his company's Agruflux tunnel liner, which is made of very flexible polythene and has a very high degree of resistance to chemicals. It's also suitable for use in water protection areas where clean drinking water is involved.

Promat's Paul Sparrow drew delegates' attention to the importance of incorporating fire protection measures in tunnels. More than 300 tunnels are protected with Promat's board systems and more than 1.5 million square metres of structural linings are protected with its spray system.

He said that preserving life by providing emergency exits and visual and audio warnings was one thing but Promat was also concerned with protecting the asset. He added that he was extremely sceptical of claims by manufacturers of water-based fire suppression systems (WBFSS) or fixed fire fighting systems (FFFS) – basically sprinkler or deluge systems – that they could also protect the structure.

"These methods are only as good as the activation system, whether it's manual or automated," said Sparrow. "The two main issues are reliability, including the risk of lack of maintenance once the tunnel is handed over to the owner; and the availability of components after some years have passed."

The alternative, he said, is passive fire protection. "It doesn't need power, water or human intervention to operate and it doesn't need turning on or off. A significant number of tunnels now have passive fire protection, so it has proven resilience."

Sparrow's presentation brought home the speed at which fires can take hold in tunnels – an increasing risk as tunnel lengths increase – but also that freight considered by many to be non-hazardous could be anything but benign.

For example, 41 people lost their lives in the Mont Blanc tunnel fire in 1999, which was caused when nine tons of margarine and 12 tons of flour ignited.

The tunnel was closed for five days and the income loss was



Above: Bekaert's eyeD system

estimated at EUR 450M (USD 475M).

Sparrow also noted the EUR 600M (USD 638M) cost of the Channel Tunnel fire in 1996, adding that Promat had quoted for a GBP 26M (USD 32M) system to protect the tunnel against fire but it wasn't taken up because "a risk assessment deemed it unnecessary".

At 1,200 degrees Celsius most building materials disintegrate and melt and even rock tunnel starts to spall. Concrete expands, loses strength and stiffness and collapses in fires and factors affecting explosive spalling include heating rate; the exposure element of the fire; moisture content; the porosity of the concrete; the age of the concrete; the aggregate type and size; and the cover to the reinforcement.

Sparrow made the point that every tunnel has to be treated as a separate case because no concrete is the same. For example, calcareous aggregate retains heat for longer.

"We must design for the worst case scenarios, not the best," he said. "We don't know what or how much will be passing through these tunnels in 100 years time so it's important that we take time out to consider the risks and protect those assets."

Protection of assets could be a description of RamArch, a system developed for Network Rail by Innovative Support Systems Ltd and described at the seminar by David Hindle.

The system, which, put simply, combines galvanised steel mesh and reinforced concrete, "looks like old fashioned technology", said Hindle. "Network Rail has a lot of old brick tunnels and brick delamination causes a lot of problems. They needed a system to give them a quick fix but that was adaptable to a permanent fix."

The system comprises a simple reinforcement weld mesh in a square pattern. The mesh is manufactured in panels, which are then deformed to form a ridge and then buckled/kinked to force the mesh to curve. The panels are joined together with standard M20 bolts to form a completed arch to virtually any dimension and profile.

"The machine that makes the RamArch panels is a bit of a trade secret but it can be described as a large steel press," said Hindle. "In fact we have two of them, the larger one puts the main crimps into the bespoke flat welded steel mesh panels supplied from a steel fabricator and the other smaller press the second crimps that cause it to bend to the required profile. The factory then fits the end connections that bolt the panels together and make the final on-site adjustments to the profile."

"The steel mesh bar sizes and spacings, together with the

finished panel height, length, width, radius, connections and finish can all be made to a required specification for a particular tunnel, whether new or refurbished."

A standard curved mesh panel is 2m long and 1.3m wide and the standard wire size is 8mm – although this can be increased to 15/16mm.

A complete arch of panels can be delivered stacked on one pallet and as each panel only weighs about 15kg, they are easy to handle. In large, high vaulted tunnels the arch can be assembled on the ground and then lifted into place by a telehandler.

"It's idiot proof and builds itself," said Hindle, adding that it can be made to any radius and is suitable for vertical shafts as well as tunnels.

The fully assembled RamArch provides a robust and stable continuous reinforced steel canopy to which shotcrete can then be applied.

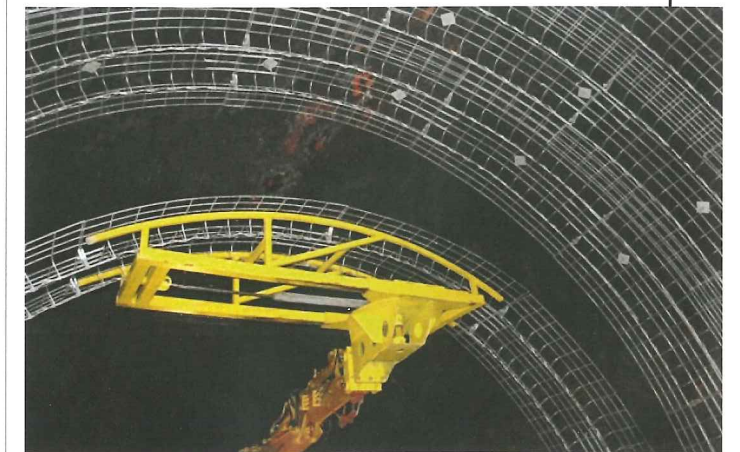
"Penetration of shotcrete is pretty good because it's such an open mesh system," said Hindle. "It can also be used with steel fibres".

The first use of RamArch was in Network Rail's Whiteball Tunnel linking Somerset and Devon. The 1,094m-long tunnel was constructed between 1842-1844 by Isambard Kingdom Brunel and had significant areas of brickwork delamination and deep open joints. Considerable water ingress was affecting some areas and severely restricting the line's speed.

Network Rail needed a rapid, safe method of temporary tunnel support that would enable a quick return to full line speed and that could later be incorporated into a permanent reinforced concrete internal tunnel lining.

The RamArch system was used to treat six areas, totalling 355 linear metres. The work was carried out successfully over six 48-hour weekend sessions.

Below: Work to install RamArch at the Whiteball Tunnel



# SHAPING UP

Tunnel navigation specialist VMT has partnered with US geo-positioning expert Topcon to create what they claim is the best solution yet for deformation monitoring



The Delta Link box is designed to control and power the Topcon MS total station. Data records are temporary stored on an internal SD card and transmitted via secure FTP transfer to a server for further analysis with the Delta Watch processing software



**Bernadette Ballantyne**

Bernadette is an engineer and freelance technical journalist

**H**ERRENKNECHT-OWNED VMT IS well known for its tunnel navigation systems, which it has sold to thousands of projects since its establishment in Germany in 1994. In April 2016 it announced that it would partner with global positioning specialist Topcon to create the Topcon Delta range of deformation monitoring products. “It consists of the Delta Link Unit in combination with a Topcon total station,” explains Sascha Schneid, product manager for deformation monitoring and innovative systems at VMT. “The total station takes readings from prisms and the Delta Link unit is a data logging device, which takes the readings from the total station and transmits this to a server where the Delta Watch software is running,” he explains.

The software takes these readings and performs statistical analysis to determine the movement between the monitoring points and the reference points as well as using a sophisticated geodetic algorithm to check the quality of the data. “It tells you relative to a reference frame whether one point has moved or not and it also gives a quality measure so there is also a measure for the reliability of the result.”

This means that the system complies with the ISO 9000 standards of quality control, which is embedded even in its most basic software so comes as standard in its products.

“That is what makes it different from competitors’ products. It is not just giving information, it also gives measure of the reliability and quality of the information,” says Schneid. “You can rely on our data.”

You can also rely on the security of the data, says Schneid, who explains that the data logger shares the information via the internet using a secure encrypted transmission.

There are other advantages for tunnelling in particular as the software is also able to incorporate geotechnical information such as groundwater measurement, ground conditions or underground instrumentation. “In general this is appropriate for all tunnelling projects. It could be a TBM or excavator or cut and



Above: Working with Delta Watch - analysing total station measurements

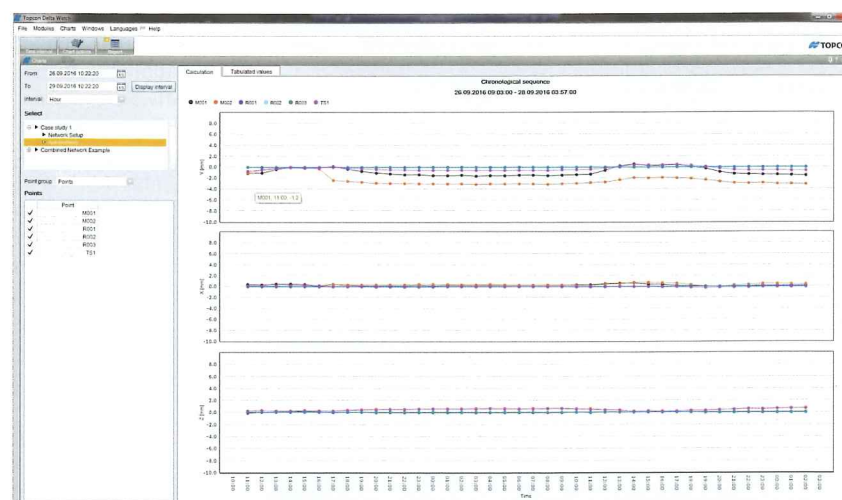
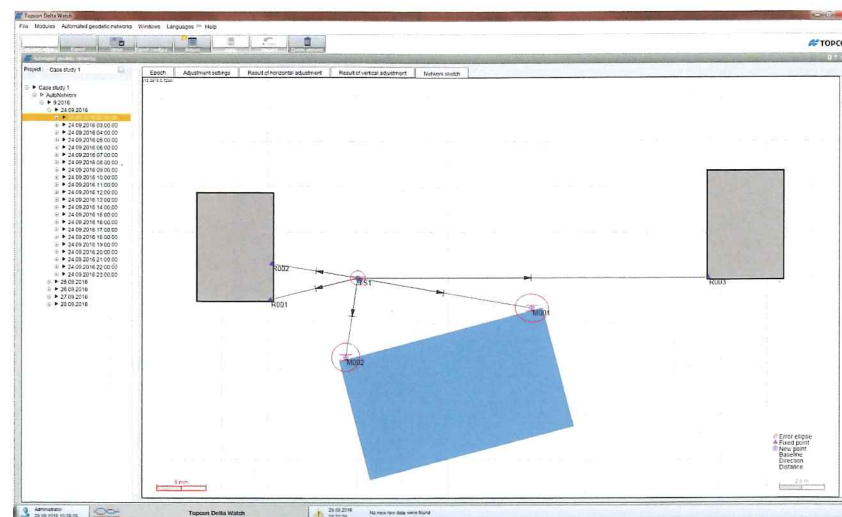
cover. There is no limitation. The software is modular and if there are any special requirements we can easily customise this by adding a module. For example in excavation it could be necessary to install monitoring inside the tunnel," says Schneid.

In addition to the Delta Link and Delta Watch the system also has the option to use GNSS data measurements using the Delta Sat add on. "The standard system takes the readings from the Topcon total station and the Delta Sat now uses satellite systems - GNSS. This is an optional thing," says Schneid explaining that for tunnelling the Topcon total station would be used for monitoring.

Another update that the system has is that the field hardware has been redeveloped to make them lightweight and easy to handle while maintaining durability and performance. "The Topcon total station is also very robust, very precise and also user friendly. It comes with several functions designed for monitoring that make life easy for people in the field," says Schneid. This includes for example the Matrix Detection function that comes as standard with the Topcon MS total station. "It enables a reflector pre-scan that automates the configuration of the prisms when the system is commissioned. Having this assistance, the field crews save a lot of time," says Schneid.

**NEW PARTNERSHIP**

For Topcon the decision to pair with VMT was a perfect fit. Topcon's global distribution network combined with VMT's heritage is described by Topcon business development manager Chris Emery as an exciting partnership. "Our product managers looked at doing something in house and then looked at if any reputable expert organisations were interested in partnering and developing a product. Conversations were struck up with VMT. It didn't take very long at all



**Top:** The Delta Watch software provides sophisticated functions for planning and analysing terrestrial network

**Above:** Besides the standard tools for processing Delta Watch provides simple but meaningful tools for data visualisation

for both organisations to realise that this is a really nice fit and monitoring is only just the start," he says.

The first Topcon Delta units were shipped in October. These early customers are experienced monitoring firms who will feed back their experience to Topcon.

"We have had a significant amount of interest. For off the shelf solutions there was a very limited number available on the market. We have had a lot of interest and a lot of enquiries from people that have been using other systems and want to test it and have indeed ordered it."

Topcon says that the system is not only designed for monitoring companies. "If tunnelling contractors feel like they have the relevant expertise within their organisation to deliver the monitoring requirements then they can purchase the Delta solution and use it themselves, alternatively if they would prefer to subcontract out the works to a specialist monitoring contractor then these are also our target audience," says Emery noting that the software presents the data but does not provide interpretation. The number of configuration tools for processing the data is one of the systems key advantages he says.

At the same time Emery says that he is in the process of setting up a demonstration site in Europe. "We can also go to people with the hardware and the software and do a day's demonstration and testing at their offices and where we can we will try to leave systems with them to test themselves and get used to it"

**Key capabilities**

- Deformation monitoring software package that process continuous, periodic or campaign deformation monitoring measurements.
- Supports key project personnel to manage risk by providing reliable data and precise monitoring results.
- Provides simple but meaningful visualisation, reporting and alarming functions.
- Optional modules create an evaluation centre for geodetic and geotechnical monitoring applications.

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# What's on

2017

## BTSYM Conference 2017

10 March 2017  
London, UK

The BTSYM Conference 2017 will be held at Pinsent Masons. The conference is only open to those aged under 35 on 1st January 2017 and is free of charge to BTS/BTSYM members. The fee for non-members is GBP 60 and includes BTSYM membership for 2017.

[www.britishtunnelling.org.uk](http://www.britishtunnelling.org.uk)

## Developing the Tunnelling and Underground space in Nigeria

29-30 March 2017

Lagos, Nigeria

A new arrival on the international conference circuit, this event is to be held in Nigeria's largest city. Speakers will include representatives from the Tunnelling Association Nigeria, the ITA, the Nigerian government and other technical associations. The aim is to realise the potential for underground space in Nigeria.

For more information please contact: [info@tunnellingnigeria.org](mailto:info@tunnellingnigeria.org)  
[www.tunnellingnigeria.org](http://www.tunnellingnigeria.org)

## 4th Brazilian Tunnelling Congress and Latin American Tunnelling Seminar

3-6 April 2017

Sao Paulo, Brazil

The fourth edition of the Brazilian Congress of Tunnels and International Seminar: "Latin American Tunneling-LAT 2017", will take place in parallel to the 9th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground.

[www.tuneis.com.br](http://www.tuneis.com.br)

## SEACETU 2017

18-19 April 2017

Subang Jaya, Malaysia

The Institution of Engineers, Malaysia is hosting the Southeast Asian Regional Conference and Exhibition on Tunnelling and Underground Space in March/April 2017 in Subang Jaya, which is approximately 27 km from Kuala Lumpur City Centre (SEACETUS2017). The conference will offer case studies and strategies that demonstrate innovation, skills and best practices.

[www.myiem.org.my](http://www.myiem.org.my)

## Symposium on Tunnels and Underground Structures in South-East Europe

4-5 May 2017

Zagreb, Croatia

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

[www.promovere.hr/congress](http://www.promovere.hr/congress)

## Swiss Tunnel Congress

30 May - 1 June 2017

Lucerne, Switzerland

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

[www.promovere.hr/congress](http://www.promovere.hr/congress)

## Rapid Excavation and Tunnelling Conference 2017

4-7 June 2017

San Diego, California

The Rapid Excavation and Tunnelling Conference is the only conference with a dedicated focus on the developments, technology, trends, and innovations that directly affect the tunnelling and underground construction industry. It is a premier event.

[www.retc.org](http://www.retc.org)

## World Tunnel Congress 2017

9-16 June 2017

Bergen, Norway

The theme of the 2017 World Tunnel Congress, which returns to Europe this year, is 'surface problems - underground solutions'. The Norwegian tunnelling industry produces tens of kilometres of drill and blast tunnel every year through the complex topography of this Nordic country.

[www.utc2017.no](http://www.utc2017.no)

## Geo M East 2017

15-19 July 2017

Sharm El-Sheik, Egypt

Recent rapid construction in Egypt has provided great opportunities for tunnel engineers to use their knowledge and talents to solve many challenging problems with innovative solutions and cutting-edge technologies.

[www.geomeast2017.org](http://www.geomeast2017.org)

## ICTUS 2017

28 August - 1 September 2017

Seoul, South Korea

The Korean Tunnelling and Underground Space Association welcomes you to Seoul. The theme is "Frontier Technologies in Tunnelling and Underground Space Technologies". It will play host to these sessions: innovations in mechanised tunnelling, developments in UG space tech, improvements in conventional tunnelling, structural and hydraulic interactions, extreme conditions, and stability.

[www.i-asem.org](http://www.i-asem.org)

## Underground Infrastructure of Urban Areas

24-26 October 2017

Wroclaw, Poland

This ITA endorsed conference is being organised by Wroclaw University and the Polish Tunnelling Group. The conference will cover "discussion on various problems related To underground Infrastructure".

[www.pbp-ita.pl/org](http://www.pbp-ita.pl/org)

## Aftes International Congress

13-15 November 2017

Paris, France

The congress of the French tunnelling association returns to Paris in 2017. For more information, readers should contact Aftes, the French tunnelling association.

[www.aftes.asso.fr](http://www.aftes.asso.fr)

## Stuva Expo 2017

6-7 December 2017

Stuttgart, Germany

The 2015 trade fair accompanying the Stuva conference exceeded all expectations. With 1,850 conference delegates and more than 550 trade visitors, around 2,400 visited in 2015 and the 2017 event is expected to build on this.

[www.stuva-expo.com/en/](http://www.stuva-expo.com/en/)

2018

## NASTT No Dig 2018

25-29 March 2018

Palm Springs, USA

Since 2001, this show has nearly doubled in size, keeping pace with the rapid growth of our industry. Cutting-edge technologies are continually being developed and introduced.

[www.nastt.org](http://www.nastt.org)

## World Tunnel Congress 2018

20-26 April 2018

Dubai, UAE

The World Tunnel Congress heads to the United Arab Emirates in 2018, and demonstrates the rise of the Middle East to the centre stage of the global tunnelling market. Experience true Arabian hospitality and enjoy Dubai, the world's most cosmopolitan city.

[www.uaesocietyofengineers.com](http://www.uaesocietyofengineers.com)

2019

## World Tunnel Congress 2019

3-9 May 2018

Naples, Italy

The World Tunnel Congress heads to the Naples in 2019 following a dramatic win at the vote at the event in San Francisco in 2016.

[www.facebook.com/events/1753343481565751/](https://www.facebook.com/events/1753343481565751/)

## ECSMGE 2019

3-9 May 2018

Reykjavik, Iceland

The Icelandic Geotechnical Society are pleased to welcome you to the XVII European Conference on Soil Mechanics and Geotechnical Engineering, held in the Icelandic capital. The theme of the conference is "Geotechnical Engineering, foundation of the future" and will embrace all aspects of geotechnics.

[www.ecsmge-2019.com](http://www.ecsmge-2019.com)

## 11th International Conference on Geosynthetics

16-21 September 2018

Seoul, South Korea

The technical program will include a Giroud lecture, 5-6 plenary lectures (special lectures), 2-3 short courses and approximately 50 parallel sessions.

[www.11icg-seoul.org](http://www.11icg-seoul.org)

## The British Tunnelling Society

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

## Delft Train Station, the Netherlands - design for safety, ventilation and air

16 March 2017

With the ongoing development of HS2, the way of managing fire safety, ventilation and high-speed pressure waves in underground stations and tunnels is a current issue, especially in built-up areas. Delft Train Station in the Netherlands is an example case history and shows an innovative example of handling ventilation and pressure waves through the overground structure while maintaining the fire safety concept.

Speaker: Robin Vervoorn, Witteveen+Bos

## The Harding Prize

20 April 2017

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

Speakers: Harding Prize finalists

## Joint BTS/BGA meeting - The Deoxygenated Gas Risk in London

18 May 2017

This meeting will look at the deoxygenated gas risk which may affect underground construction works in London. This has been the subject of recent research and tonight's meeting will cover this, current thinking and the practical aspects to be adopted on projects.

Speakers: Tim Newman, Geotechnical Engineer, Tideway Project

## Paddington Bakerloo Line Link Project

15 June 2017

The meeting will describe Transport for London's / London Underground's Paddington Bakerloo Line Link project and cover such aspects as: the Sprayed Concrete Lining works, the cross passage excavations, the new switch room excavations, the link tunnel breakthrough with secondary lining, the square works in the lift lobby and the lower concourse strengthening.

Speakers: The CSJU / LU delivery team

## High Speed Railway Tunnel Projects & General Tunnelling Status in China

21 September 2017

This presentation will be given by the China Railway Tunnelling Group Contractors & China Railway Engineering Equipment Group. It will discuss the status of high speed rail technology in China with a particular emphasis on the design, construction techniques and use of TBMs in the tunnel sections of current major projects. An overview will be given of how the roles of client, designer and contractor operate in the Chinese market. The presentation will cover the past, present and future of high speed rail in China; the latest advanced technologies in rail, trackbed, signalling and power; principal design technology; construction methods, technology and equipment; and operations and maintenance.

Speakers: Kung Wang and Yali Han

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

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