

INTERNATIONAL EDITION

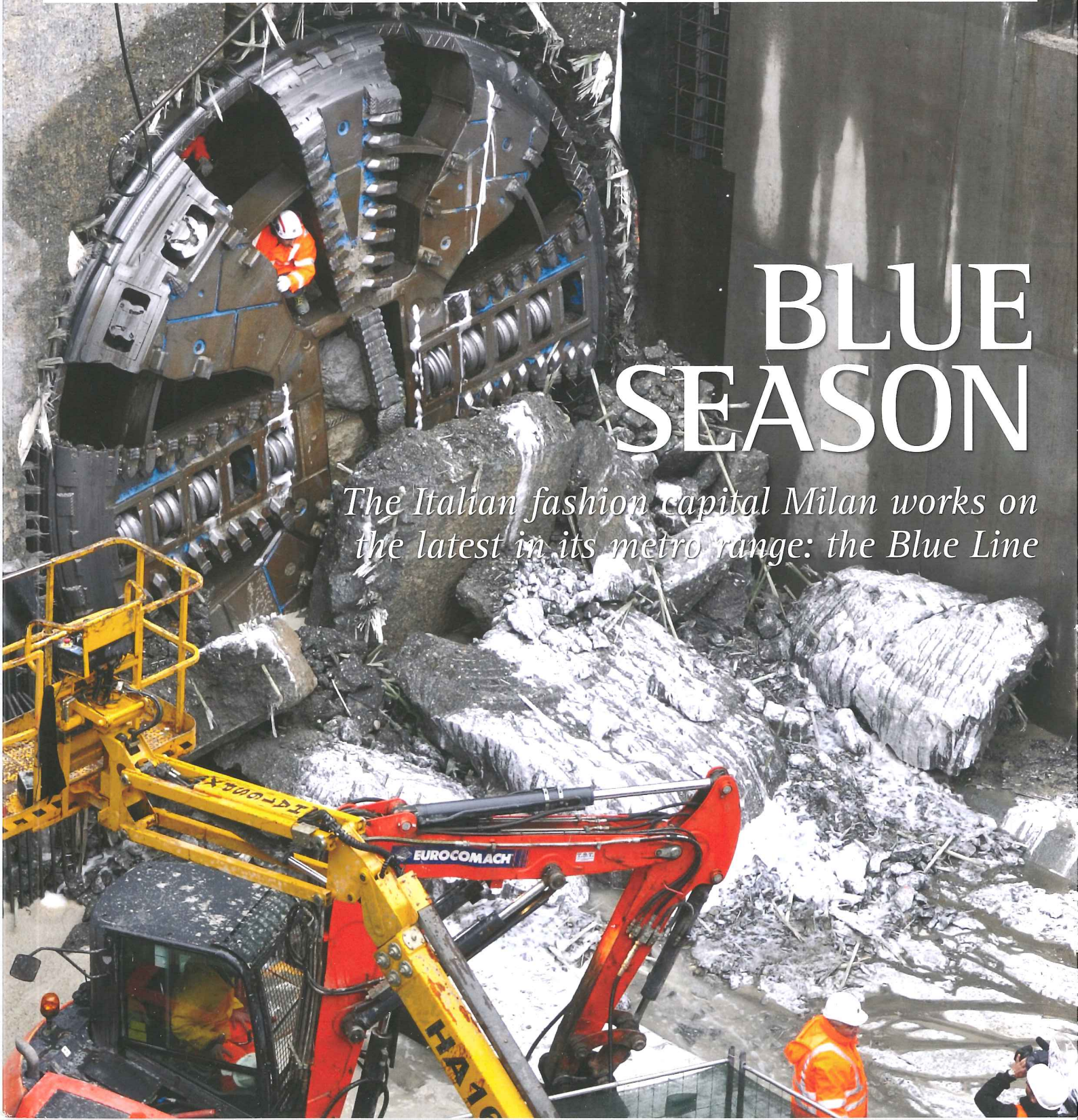
December 2016

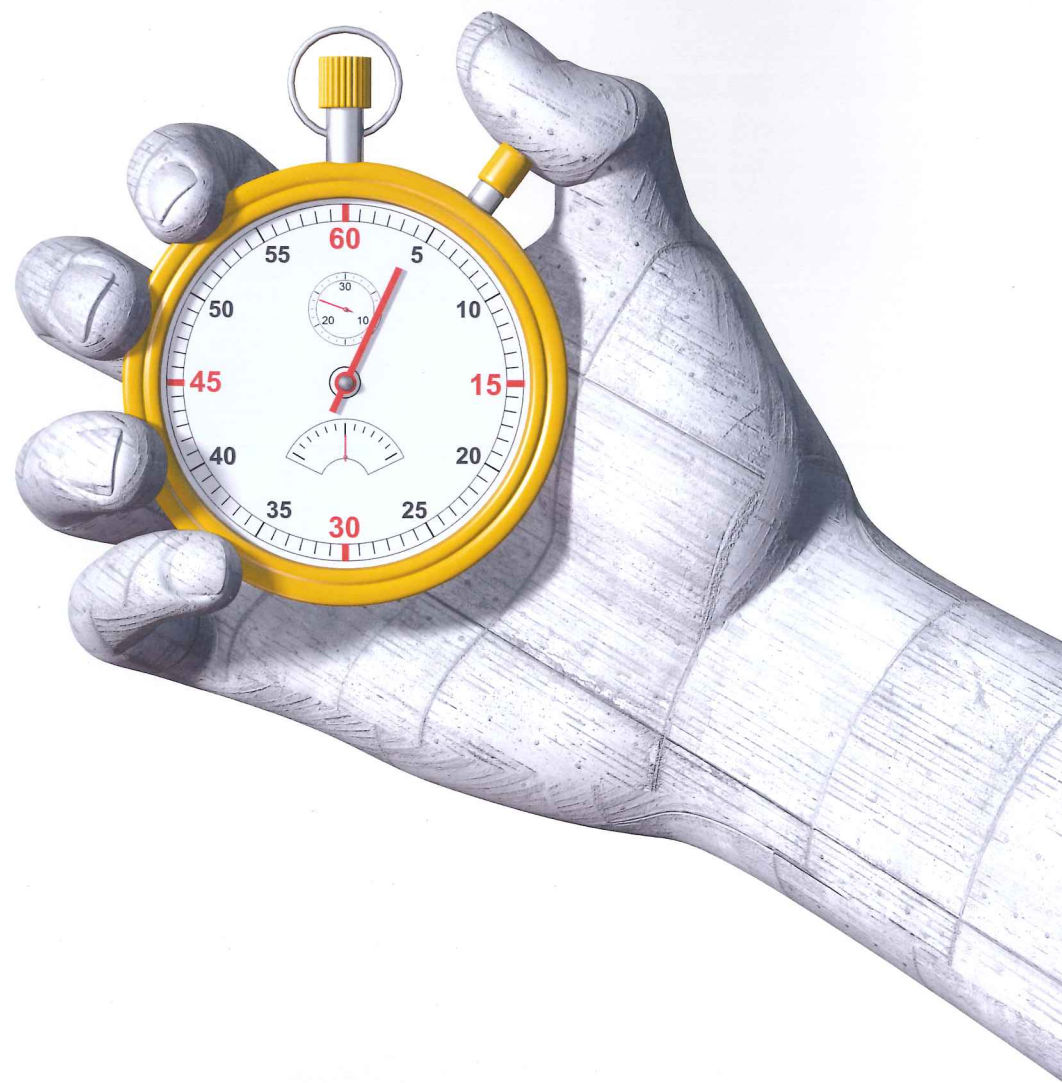
# Tunnels

AND TUNNELLING

## BLUE SEASON

*The Italian fashion capital Milan works on the latest in its metro range: the Blue Line*





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## BLANKA TWO

**R**umblings from the City Hall of Prague suggest a new tunnel complex may be planned for the Czech capital. The story was broken in late November by the economics-focused Prague daily newspaper 'Hospodářské noviny'.

The project hopes to complete the Prague's inner ring road and resolve the city's traffic problems. According to the newspaper, around CZK 80M (USD 3.14M) has been put aside for design and study preparations in 2017. Of course the final project will be far more, around CZK 50bn (USD 1.97bn) according to early estimates.

Although Petr Dolínek, deputy mayor of Prague, who has responsibilities for transport and finance, admits that the project could come in significantly more expensive.

The alignment is still unknown, but it will connect to the existing Blanka complex. Which could make things interesting on the public relations front. The earlier 5.5km Blanka tunnel project saw cost and time overruns following several collapses. In 2010 a 15m crater resulted from a collapse, which temporarily buried an excavator with its operator – who was thankfully recovered without injury – and in 2008 the ground fell through in a public park causing a 20m crater.

In 2011 it was announced that the cost of the project would increase by CZK 10bn to CZK 37bn (USD 2.08bn in 2011) and the topic became politically

### Alex Conacher

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



charged with the sitting administration blaming its predecessors and vice versa. The project eventually opened in 2015, four years late, but the infrastructure is in place.

Now, Dolínek sets his sights on the missing piece of Prague's road system, and wants to see it completed within 10 years. Although *Hospodářské noviny* quotes a representative of Satra, a company involved in the design of Blanka who suggests that a planning period of six or seven, maybe even more years is realistic. Blanka preparations reportedly lasted 12 years with construction running another eight. Dolínek, then, may be an optimist. But political support for tunnelling is usually a good sign.

Of interest to engineers on the 'Blanka Two' project, and surely the focus of future articles, is a section of road near the river, Povltavská Street, which is too narrow for the desired four lanes. Designers will need to resolve this. Reportedly the solutions are likely to be a two-level surface road, a double-deck tunnel or a surface road and tunnel road combination.

It is this area that gets gridlocked at the slightest disruption, and a tunnel is still a preferred solution for Prague

### Cover

*Tunnels and Tunnelling* visits the Milan Metro's Line Four, or Blue Line for an update earlier this year.



### Next issue

In the next issue of *Tunnels and Tunnelling* we visit Herrenknecht's factory in Schwanaue to talk utility tunnelling with the experts there. Additionally there is a report from the nearby Rastatt Tunnel project and a look at the Rhondda Tunnel Society.

### This month...

#### 20 YEARS AGO

Camponon Bernard-Maeda (CBM) the Franco-Japanese JV has been ejected from its USD 195M deep tunneling contract in Hong Kong following a row with the territory's Drainage Services Department (DSD). The department is now planning to re-invite tenders for completion of the 25km-long tunnel system. However this will delay completion of the project by at least a year to 1999. Construction has been at a standstill since July after CBM encountered severe groundwater problems on two of its six tunnel drives. CBM shut down all work rather than continue partially. The firm claimed that to carry on would jeopardise the lives of the TBM crews.

*Tunnels and Tunnelling, December 1996 p.9*

#### 30 YEARS AGO

The Dillingham/Obayashi joint venture has returned the lowest bid for the next section of the Red Line extension to the north for the Washington DC Metro. The contract calls for a 692m-long twin tube rock tunnel. Dillingham/Obayashi intends to use NATM if it secures the contract. The results of this bid reveal two interesting points. First that US contractors are beginning to accept and employ NATM. Secondly, a change in relationship between contractor bids and the client engineer's estimate. In this case, and some other recent cases the low bid was higher than the estimate. In past years contractors have bid up to 40 or 50 per cent under the estimate.

*Tunnels and Tunnelling, December 1986 p.10*



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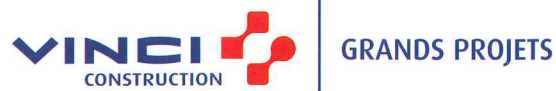
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## ITA TUNNELLING AWARDS 2016

**INTERNATIONAL** - The winners of the ITA Tunnelling Awards were announced last month. The event, held in Singapore in November, recognised eight tunnelling projects and two individuals for outstanding industry achievement.

The host nation managed to win considerable recognition in several categories.

The projects recognised were DTL 3 Contract 937 - Fort Canning Station and Tunnels in Singapore; the Chongqing Hongqijie Metro Station in China.

The Vauxhall Station Upgrade Project in the UK was awarded the 'Renovation/Upgrading Project of the Year Award'.

The Technical Innovation of the Year was awarded to Line Four of the Rio de Janeiro Metro in Brazil for large diameter (11.51m) shield tunnelling in pure sands bounded by two bands of hard, highly abrasive rock. Hybrid EPB shield technology was used.

The Environmental Initiative of the Year was the Emscher Project in Germany. This category was awarded to a project

based on its end-use, rather than a specific engineering achievement, but the project will be vital to mitigate damage from a century of coal mining activities.

The "Activity Based Safety Improvement System" (ABSIS) on a cable tunnel in Singapore scooped the Safety Initiative of the Year. It involves videoing construction activities then making workers watch themselves in action.

The ITA recognised the Jurong Rock Caverns in Singapore for the innovative use of underground space. These enormous, cathedral-like caverns are intended for oil storage.

The underground storage of the country's reserves saves valuable surface space and secures the oil, for strategic reasons.

Martin Herrenknecht received the Lifetime Achievement Award for "his remarkable contributions to tunnelling". After studies at the Konstanz University of Applied Sciences, from which he was diplomed in 1964, he founded his own company in 1975, specialised in TBMs.

Derek Eng was named Young Tunneller of the Year. He works as an assistant manager in MMC Gamuda's tunnelling department and, according to the ITA, has been "vocationally called to empower young tunnellers using his hard-gained experiences and knowledge".



Martin Herrenknecht is recognised

### Tunnelling finishes on D.C.'s Anacostia River Tunnel



The TBM is lowered in D.C.

**USA** - The Lane Construction Corp, a U.S. subsidiary of the Salini Impregilo Group, together with its subsidiary S.A. Healy Co. and Parsons (IHP JV) have completed the excavation of the 12,500ft- (3.8km-) long Anacostia River Tunnel in Washington D.C., Salini Impregilo announced on 8 November.

It's one of the four tunnels for DC Water's Clean Rivers Project aimed at reducing the pollution of its rivers. The Anacostia tunnel was designed with an inside diameter of 23ft (7m), and excavated by an EPBM.

The tunnel runs south from a site near RFK Stadium to the Poplar Point Pumping Station. Its alignment is approximately 100ft (30m) below the surface and runs underneath the Anacostia River, CSX railroad tracks, the new Interstate 695, and the WMATA Green Line.

Salini Impregilo said the tunnel's completion date is December 13, 2017, and the JV will complete the project by constructing six shafts of varying sizes, four diversion structures, and three connecting adits.

### New York to improve its highway tunnels

**USA** - On 5 October Governor Andrew Cuomo announced a plan to update MTA's Bridges and Tunnels, which includes colourful LED lights, flood resiliency measures and additional security.

As part of the New York Crossing Project, the state will implement new tunnel barriers to control major floods for the Queen-Midtown tunnel and the Hugh L. Carey Brooklyn

Battery Tunnel.

Previously, New York's tunnels were built to protect against a 100-year flood, but the devastation wrought by Hurricanes Sandy and Irene demonstrated a need to enhance protections to withstand a 500-year flood. Tunnels will have new barriers installed to block floodwater from entering with water-tight barriers to protect the tunnel and its facilities. Additionally, tunnels will have increased submersible pumping capacity to protect against flooding.

The plan will also institute state-of-the-art automatic tolling at all MTA bridges and tunnels - reducing traffic congestion and decreasing emissions, the governor said. The state will also deploy technology and security personnel to high-profile crossings in New York to enhance public safety and fortify anti-terror efforts.

Along with adding LED lighting, the MTA said it will provide a renewed focus on public art "to ensure our infrastructure projects reflect

the grandeur of the Empire State." Under the Governor's plan, New York will redesign tunnel plazas with cutting-edge veils equipped with LED capability, and gantry structures supporting the new electronic toll equipment will feature artistic "wave" designs that will vary in size and scale.

"By investing in New York's transportation network today and equipping it to meet the challenges of tomorrow, we are cementing our state's position as a national leader in 21st century infrastructure and cutting-edge innovation," governor Cuomo said. "From speeding up commutes and reducing emissions on key roadways with automatic tolling to bolstering resiliency on our bridges and tunnels and increasing security at key checkpoints, this transformational project will revolutionize transportation in New York and ensure that our state is built to lead for generations to come."

Funding for the bridge and tunnel improvements is allocated as part of the MTA's USD 27bn capital plan.

timetri

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## LOVSUNS BREAKTHROUGH ON ISTANBUL SEWER

**TURKEY** - The TBM boring the Ayvali-2 Tunnel, a sewer bypass in Istanbul, broke through in September. The 3.91m Lovsuns EPBM drove the 2km-long tunnel beneath the Zeytinburnu district through sandstone, siltstone, clay and soil.

The TBM launched from a 21m-deep launch shaft in December 2015 and broke through into the 12m deep target shaft after around nine months of excavation. It should have taken less time but problems with muck transportation during the winter period were more protracted than expected.

The regular overburden was between 8 and 40m, but the final 150m leading up to the target shaft saw the tunnel pass within 6m of the foundations of the nearby residential areas.

After this first breakthrough and disassembly of the TBM, the machine will be reassembled in the launch shaft in Ayazaga to drive a second, 7.29km long discharge tunnel between the existing wastewater tunnels of Kemberburgaz and Ambarli. Here the ground will be rock and sandstone. The TBM for the Wastewater Tunnel was one of the first contracts for the Lovsuns Company designed by experienced ex-Lovat engineers and manufactured at the Chinese facilities of LNSS.



Breakthrough on the 3.91m-diameter sewer project

### Lee Tunnel wins at Concrete Society Awards

**GREAT BRITAIN** - The Concrete Society recognised the Lee Tunnel project as the Outright Winner at its awards on 17 November. The project was hailed for "pushing the technical boundaries of what is possible with concrete".

The project comprises five shafts, with the diaphragm walls the deepest undertaken in the UK at 90m. A 7m-diameter, 7km-long tunnel connects the shafts. The steel-fibre-reinforced concrete for the slipformed tunnel lining took 18 months to develop, resulting in a self-compacting concrete with a retention time of four hours



The Lee Tunnel shaft broke UK records for depth

encompassing up to 15 constituent materials. The innovative slipformed shaft construction also incorporated steel fibres to reduce substantially the quantity of standard reinforcement.

Richard Kershaw of Cemex UK Materials, concrete supplier to the project, said, "We are very honoured to receive such acclaim from this most prestigious of awards. Concrete was the only realistic material choice for this structure. Cemex is proud to be part of this momentous scheme and be part of a legacy to London, which will help prevent 16M tonnes of sewage entering the River Lee and Thames each year."

The Society Awards judging panel said, "The Lee Tunnel was the most outstanding structure and therefore outright winner for its technical achievements in the use of concrete, its demanding placement conditions and innovative structural solutions. The statistics for concrete volume placed are impressive; the innovation required and final execution is exemplary. This project pushed the technical boundaries of what is possible with concrete."

More than 400 members, guests and construction industry representatives attended The Concrete Society Awards Dinner held at the Grosvenor House Hotel, Park Lane, London on 17 November. This event celebrates excellence in concrete and is the longest-running awards programme in the UK construction industry, now in its 48th year.

### TBMs ready for Lucknow Metro project

**INDIA** - The TBMs set to bore the Lucknow Metro are in transit. The two 6.52m-diameter Terratec EPBMs will bore the city's Phase 1A north-south line. The project consists of twin 1,812m-long tunnels. The TBMs will be launched and received at ramps.

The 36-month, USD 1bn contract, which was awarded to Tata-Gulermak JV in April, also includes the construction of three new underground stations at Hussainganj, State Secretariat (Sachivalaya) and Hazratganj.

The machines will be equipped in a soil configuration with tools that can be changed for 17" disc

cutters to bore through diaphragm walls, and in case of unexpected obstacles.

The first TBM arrived in November at the Sachivalaya worksite while the second will arrive in December.

A spokesman for the manufacturer said: "The machines will initially be launched on twin 780m drives towards Hazratganj, where they will bore through local geology consisting of stiff to hard clayey silt and medium to dense silty sand, with an average overburden of 4-10m.

"Following the initial drives to Hazratganj - where the machines will pass beneath historic buildings in the Capital Plaza of Hazrat Ganj - the machines will return to the shaft at Sachivalaya and be deployed on their next, 613m-long, drives towards Hussainganj.

"From there, they will continue on a further 419m - crossing underneath the Haide Nalah canal - to the cut and cover ramp near Charbagh station."

The tunnels will be lined with universal segmental rings in a 5-key configuration. The segments will be 275mm thick by 1,400mm long. Work on Phase 2 should begin in 2018.

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The TBM for the Northgate Link LRT project in Seattle

**US Cities approve tax measures to fund transit**

USA - Voters in Seattle and Los Angeles, two of the largest cities in the US, approved measures to further fund infrastructure development for public transit on Tuesday, 8 November.

In Seattle the Sound

Transit 3 proposition called for completing major mass transit extensions every few years over a 25-year period, with 62 new miles of light rail in the Puget Sound region.

Of the light rail plans included in the measure, at least one includes a tunnel component. The plan is worth about USD 54bn.

Los Angeles voters passed

Measure M with more than 69 per cent of the population's support. It's a sales tax that will fund infrastructure repair and development including expanding rail, subway and bus systems. The Los Angeles County Metropolitan Transportation Authority expects the measure to generate USD 860M a year in 2017 dollars. The proposed projects will be built over a 40-year period.

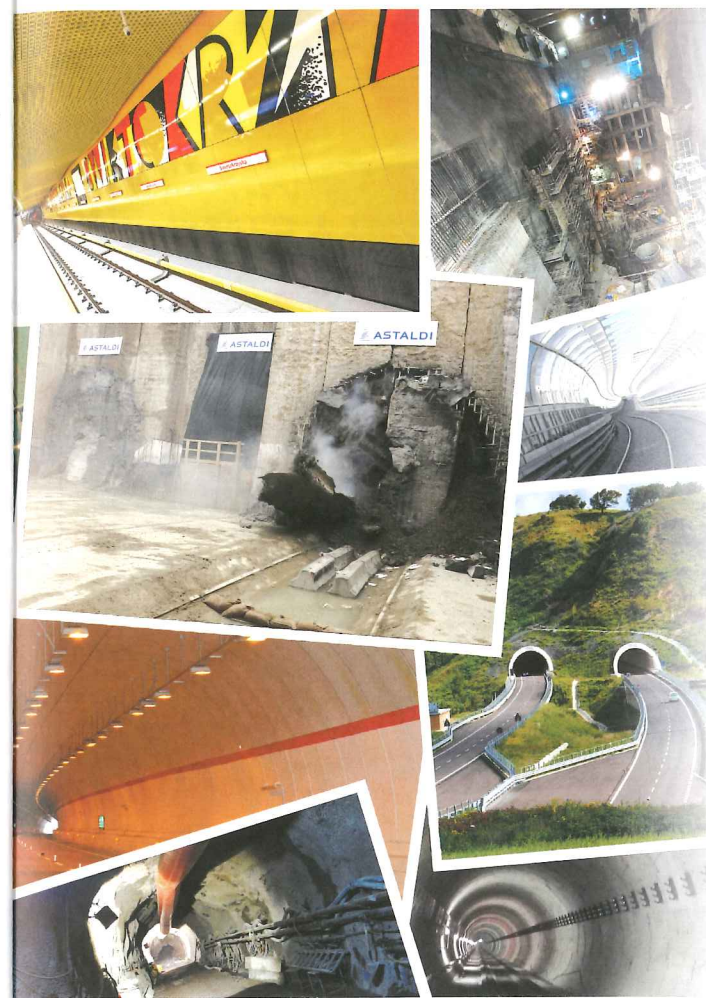
Metro released a statement on their Web site, "Thanks to the public for putting their faith in us to build a transportation system for today, tomorrow and beyond. Together, we are making history and are showing the nation – even the world – how to be bold and forward thinking as we continue to transform transportation."

**Queen Creek Tunnel installs LED lighting system**

USA - Phoenix's Queen Creek Tunnel on US 60 is Arizona's first tunnel to have a light-emitting diode (LED) lighting system, the Arizona Department of Transportation announced on 7 October.

The new lighting system will improve visibility in the tunnel, which was built in 1952, by using an adaptive control system that will adjust the lighting level based upon ambient light and weather conditions outside. It will also save money on electricity and reduce the need for maintenance.

The Arizona Department of Transport said that it secured a USD 1M federal grant in 2014 to help fund the refurbishment project.



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**TUNNELLING BEGINS ON NORTHERN LINE**

GREAT BRITAIN - Tunnelling for the first extension to London's Tube network since the 1960s began last month. The running tunnels towards the Kennington loop are being constructed by 15t Schaeff excavators and lined with sprayed concrete and should take about three months to build. The contractor is the Ferrovial Agroman and Laing O'Rourke JV with OTB as designer.

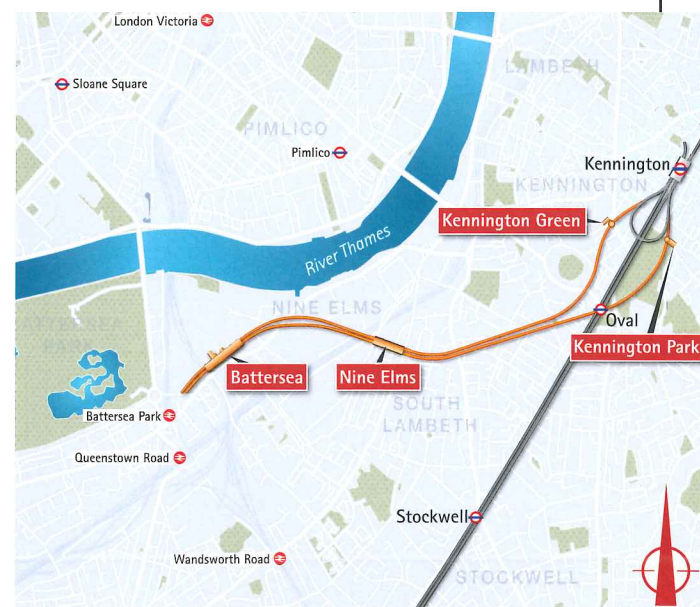
Two 25m-deep permanent shafts have already been sunk, allowing tunnelling to begin. Once the extension is complete, the shafts will remain in place and provide ventilation, cooling and emergency access to the tunnels. The 18,000t of spoil has been removed via barge to turn landfill sites into arable farmland. A Transport for London spokesperson added: "The works will culminate with the building of a step-plate junction around the existing Northern line loop tunnel. This is a technical and very complex piece of work involving hand-mining and very little machinery.

"The step-plate junction will take around seven months to build and will be the first time that those working on the project interface with the existing railway."

The mining diameter is 6.1m with a finished i.d. of 5.2m. The Kennington Park tunnel and step plate junction will be 160m long in total while the Kennington Green tunnel and step plate junction will be 270m. The works will predominantly be in London Clay and the shotcrete will vary between 150-300mm depending on location.

A stub tunnel will be constructed at the reverse side of the shaft ready to receive the TBMs in late 2017. The 6m-diameter NFM machines were being transported to London as *Tunnels and Tunnelling* went to press. They will be assembled at a Battersea work site and launch on their 2.5km journey in early 2017. They are due to break through into the Kennington shafts in late 2017.

Martin Gosling, head of the Northern Line Extension at London Underground, said: "The tunnelling works at Kennington



The Northern Line Extension to Battersea will serve a new housing development in the area and, planners hope, regenerate a somewhat neglected area

represent a significant milestone in the construction of the Northern Line Extension which will bring Battersea and surrounding areas to within 15 minutes of the West End and City. Construction is now well underway in Kennington and involves a lot of complex, highly skilled construction work.

"It is a significant step forward in the project which, once complete, will help us to support jobs, create homes and growth in this area and keep pace with the capital's rising population."

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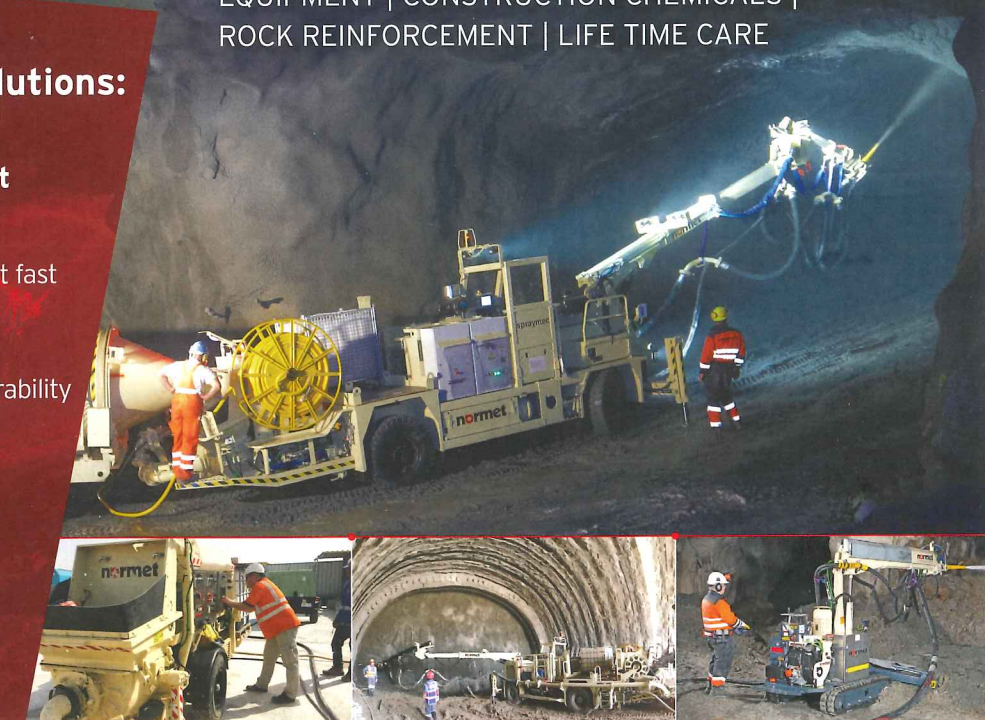
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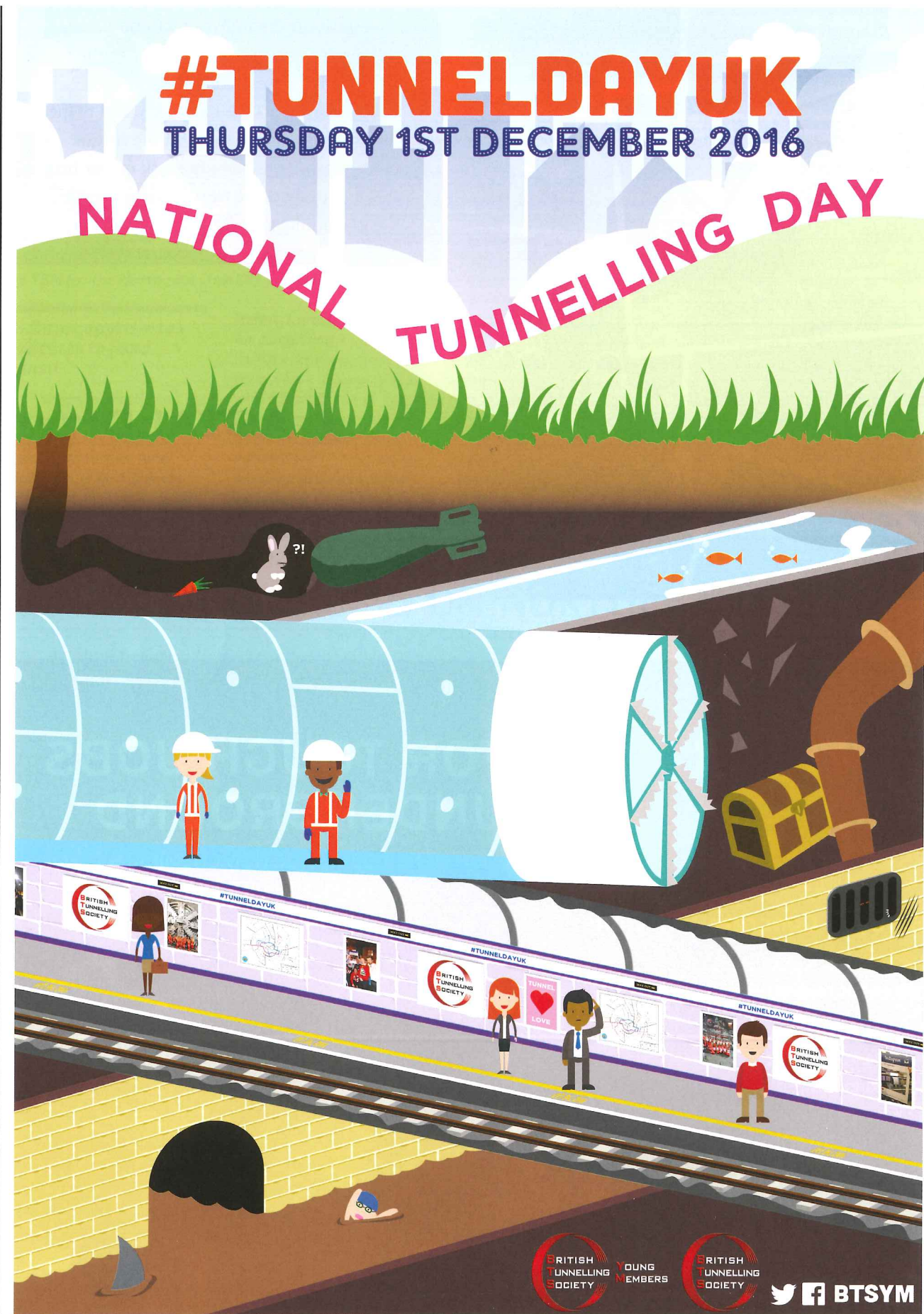
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## BRITAIN CELEBRATES SECOND NATIONAL TUNNELLING DAY

**GREAT BRITAIN** - The BTS is preparing for the second UK National Tunnelling Day as *Tunnels and Tunnelling* goes to press. Spearheaded by the society's young members group, the event aims to "generate interest in the great number of world class tunnelling projects currently being undertaken in the UK and to promote the industry (and its many professions) to students of all ages and the general public".

The day is held annually on the first Thursday of December, chosen to keep it

on a weekday close to the feast of Saint Barbara, the patron saint of tunnellers, miners and explosives workers.

A spokesperson for the BTS said: "As part of the day we are running a media campaign on Twitter under the hashtag #TunnelDayUK."

The society would appreciate your company's help with the promotion of the day on social media networks. We would like people and organisations to tweet and share interesting images, stories, news items (historical or current)

using the designated hashtags and ultimately get it trending on social media channels.

"For the first National Tunnelling Day in 2015 there were more than 700 tweets using #TunnelDayUK with a reach of 1.5 million users and this year we are hoping it will be more successful."

While the day will have come and gone by the time readers receive this December issue, *Tunnels and Tunnelling* hopes to showcase some of the highlights in the New Year.

### Siphon Tunnel activated

**USA** - A new water tunnel in New York connecting Brooklyn to Staten Island is now activated following a ceremony on 29 October. The tunnel saw years of delay following the devastation of Super Storm Sandy in 2012.

The USD 250M tunnel ensures drinking water supply in the aftermath of a disaster. The 2.6km-long, deeper tunnel can deliver up to 150M gallons of water per day to Staten Island from Brooklyn under the New York Harbour.

Contractor Tully/OHL USA JV procured a 3.8m diameter EPB TBM from Caterpillar in 2012, which was designed to drive through highly variable clays, sands, weathered rock and boulders. It was launched from the 35m-deep Staten

Island shaft, boring towards the 40m deep Brooklyn shaft, in August 2012. The EPBM progressed approximately 1,600ft (488m) towards Brooklyn when operations were suspended on the evening of October 28, 2012, in advance of the approaching Hurricane Sandy.

The storm flooded the Staten Island shaft and the excavated tunnel with sea water and severely damaged the TBM.

The saltwater severely corroded the TBM, which sat idle until July 2013. During that time, CAT announced its impending closure of its TBM business, and the contractor looked to other manufacturers. Robbins helped rebuild the machine, much of which required the work to be done in the tunnel under water pressure. Crews were

able to return to mining on April 14, 2014.

The 72-inch (1.8m) diameter siphon was excavated at a depth of 100ft (30.5m) and replaces two existing connections that run from Brooklyn to Stapleton and Tompkinsville on Staten Island. Mining reached completion in early 2015.

"Our city is better prepared to tackle 21st century threats like Sandy today than ever before. This water tunnel is one measure that will help Staten Island spring back to action in the event of a disaster that would disrupt the water supply," said mayor Bill de Blasio.

"Measures like these are being implemented across the City, from Red Hook to the Rockaways, our City is becoming Safer and more resilient every day."

### Death on SW4 halts all tunnelling in Edmonton

**CANADA** - A 44-year-old man died on 1 November underground on the SW4 sewer tunnel in Edmonton, Alberta.

The City of Edmonton, which maintains its own in-house tunnelling group, shut down all tunnelling operations following the fatality. Edmonton currently has four TBMs deployed for sewer work around the city. SW4 comprises a 1,528m-long tunnel, 3m in diameter, and two shafts.

No other workers were hurt, and the name of the deceased has not been released.

### Sinkhole appears in Fukuoka

**JAPAN** - A sinkhole, possibly resulting from nearby underground railway construction work, swallowed a five lane street in the Japanese city of Fukuoka last month. The city is extending one of its metro lines.

The depression was caused by two smaller holes that grew to form the 30m-wide, 15m-deep expanse. No one was injured, but utilities were disrupted.

Global media was impressed by repair works, which restored services and re-opened the road within one week.



The Siphon project was heavily delayed following the 2012 hurricane

**US elects Donald Trump president**

USA - Businessman Donald Trump secured more than 270 electoral college votes to become the 45th president of the United States on 8 November.

In his acceptance speech Wednesday morning he called for infrastructure development. "We are going to fix our inner cities and rebuild our highways, bridges, tunnels, airports, schools, hospitals. We're going to rebuild our infrastructure, which will become, by the way, second to none, and we will put millions of our people

to work as we rebuild it."

Trump's campaign cited numbers from the National Association of Manufacturers (NAM), which said the nation has a 10-year funding gap of approximately USD 1tr. While campaigning Trump said his infrastructure plan aims to achieve a target of investment to fill this gap.

**Tunnelling event cancelled without warning**

NETHERLANDS - A tunnelling conference was cancelled at the last minute this month. According to sources, a number of delegates and

speakers had arrived for the Global Tunnels Safety and Fire Protection Summit only to be told by the hotel that the bill had not been paid and the organisers failed to turn up.

The event was to be held at the NH Hotel at Schiphol Airport and was organised by Arshbi. Arshbi could not be reached for comment. Refunds had been requested by some delegates as *Tunnels and Tunnelling* went to press, but apparently no reply had been received.

**Bertha nearing the tunnel's deepest point**

USA - Seattle Tunnel Partners

passed the 60 per cent mark of tunnel boring late in November, just before the US celebrated Thanksgiving. As of this 21 November, crews had mined 5,774 of 9,270ft (1,760 of 2,825m) and installed 880 of 1,426 concrete tunnel rings.

Bertha, the SR 99 tunnelling machine, is located near Virginia Street, between First and Second avenues. With the top of the cutterhead now approximately 210ft (64m) below the surface, crews were nearing the deepest point of the tunnel drive.

Bertha has advanced well since the lengthy shutdown.

**NEW PRESIDENT FOR INSTITUTE OF FIRE SAFETY MANAGERS**

GREAT BRITAIN - Fire safety consultant Graham Green is the new president of the Institute of Fire Safety Managers (IFSM). The appointment was made at the annual Fire Sector Summit held at the Royal Academy of Surgeons in London.

Currently working for London Bridge Associates, Green has been managing fire safety for the last 11 years both within the fire brigade and as a fire safety consultant in the private sector. He currently manages fire safety on a number of projects across London including Crossrail, various London Underground jobs, the Houses of Parliament and Berkeley Homes.

Green has been recognised for his continuous contribution to the IFSM over the years and has been encouraging the next generation of members in his previous role as membership secretary.

The IFSM is a professional body of highly-respected individuals and companies who, according to its mission statement, all share the same objective: "To raise the awareness of fire safety at a local, national and international level, promoting fire prevention, fire protection and reducing the risk from fire as far as reasonable practicable."

Chris Richards FIFSM Tech IOSH is the immediate past president.

To find out more information about the society and its activities, readers can visit its website: [www.ifsm.org.uk](http://www.ifsm.org.uk)

Right: Graham Green, pictured left in each photo, is the new IFSM president



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*Left: The 3.8 m diameter Robbins Main Beam TBM is now boring the 8km Bellwood Tunnel in Atlanta, Georgia, USA after being walked forward 30m into a starter tunnel. The Bellwood The alignment runs from an inactive quarry and run below a water treatment plant and reservoir before ending next to the Chatta-hoochee River. The project is an emergency water supply tunnel being bored through granite*



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# COWI UK COMES TOGETHER

As Cowi acquisitions Donaldson Associates and Flint & Neill prepare to form Cowi UK in the New Year, *Tunnels & Tunnelling* speaks to **Andy Sloan**, managing director of Donaldson Associates about the new changes and the journey from "Donaldson's" as it is known in the UK, to Cowi



**Above:** Hong Kong's XRL C824 project, for which Donaldson Associates recently won a Saltire Award

**W**.A. FAIRHURST & PARTNERS does not look the most significant entry on Andy Sloan's curriculum vitae. But the managing director of Donaldson Associates underlines that period in his career as vital to the company's current relationship with its new owners. Cowi bought Donaldson Associates in 2014 after just three months' due diligence. The speed of the move was in part thanks to a six-month placement with Cowi that Sloan undertook back in 1995, during the early stages of the Copenhagen Metro. "That was one of the reasons Cowi were at the top of our list of who we would like to sell to," says Sloan. "I was impressed

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



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with what I saw there. Funnily enough we were at the top of the list of UK companies they were looking at buying.”

Having joined the Donaldson board in 1999 Sloan was made a kind of operations director charged with looking at the “delivery of the product”. But the intention when he joined the company was to help founder David Donaldson develop the business from 15 people into an entity that could “undertake large and complex underground and geotechnical projects on a global scale”. By the time the company was sold to Cowi, with a staff of 145, it was a major player in the UK with some overseas work.

**LIFE UNDER COWI**

Preceding the buyout, Donaldson’s had hit a glass ceiling. Largely this was a size issue. Until now Donaldson’s has worked as a sub consultant undertaking technically challenging roles, either for another consultant or taken on directly by a contractor to tackle part of a project. However, the company’s management

**Above and below:** The Glendoe Project in Scotland

**Right:** Large span cavern for the Express Rail Link C824 project

wants to form joint ventures and gain a seat at what Sloan calls the “top table” with other consultants to fulfil a larger part of major projects. Donaldson’s needed to sell.

As for Cowi, the Danish company was actively trying to strengthen its tunnelling capabilities, but it had specifically been looking at the UK. Already owning Flint & Neill, it had set its sights on purchasing a British tunnelling firm to cement its presence in the market.

A year after being bought out, the mother company decided that worldwide it wanted to consolidate its various companies under the Cowi brand. The five year plan, which also targets a doubling of revenue by the time it concludes in 2020, will see the formation of Cowi UK from 2017. Similarly, Buckland & Taylor, Jenny Engineering and Cowi Marine North America became Cowi North America earlier this year.

The new UK-based Cowi will be formed of three parts: Cowi Tunnel (the largest unit), Cowi Bridge and Cowi Marine. The final part still quite small, but the first two are established



being based off Donaldson’s and Flint & Neill. Head of Cowi International Lars Hauga will join Andy Sloan of Donaldson’s, Flint & Neill boss David Mackenzie and Hugo Wood of Cowi Marine to form the new board.

There has been a degree of confusion in the last few years over whether clients were dealing with Donaldson Associates or with Cowi. So it was decided that the best move was to adopt the Cowi brand sooner rather than later. According to Sloan, existing customers should experience no difference whatsoever. They will still be dealing with the same people that they have for the past 10 or 20 years and be dealing with the same locations.

As for the staff, he admits that as well as excitement, there is a degree of sadness in seeing the end of the brand. “A lot of my senior staff have been here for many years. Three or four of us are coming up to 20 years in the next year. There is no reticence, but is a degree of sadness in seeing the history go. But we are not going to airbrush it out of existence. There is a strong legacy and the name and history will still be mentioned on websites for



instance, just as Steve Hunt has done for Buckland & Taylor in Cowi North America. So while there is sadness, we had reached a glass ceiling as far as the size of the projects we could take on goes. So there is excitement at the opportunities that the rebranding and support of Cowi can bring us.”

**INTERNATIONAL INVOLVEMENT**

While Donaldson’s has been involved in international projects before, and has operated an office in Hong Kong since 2010, Sloan has already seen a jump in this area.

“There has been a sea change now in the markets we are looking for and how we interact with other parts of the company. We have colleagues from all over the world in our UK office now, and we are sending our people elsewhere to work on projects all around the world.”

As with the assembly of project teams, the decision on which markets to focus on is also taken collegially. Every quarter there is an international management meeting with 30-35 directors meeting in different parts of the world to discuss the management of the 1,500 Cowi International staff. They identify targets they’re particularly interested in and develop strategies. There are five people running the tunnelling business globally and these people will meet more regularly, being in touch at least once a month.

In terms of cultural clash – Sloan says there hasn’t been any friction but they do share ideas. He points to UK CDM regulations as an example. “Our colleagues around the world are quite interested and willing to listen to why we think CDM is

**Above:** The Glendoe hydropower project is located in the highlands of Scotland

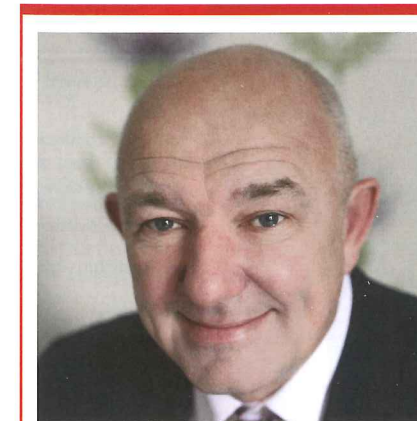
best practice globally. That is, looking at risks inherent in the design from a safety perspective. We are speaking to different areas to spread it.”

**FINAL THOUGHTS**

So is the target of doubling revenue achievable? Sloan thinks so. “I think if you break it down into bite-sized chunks and look at the number of people that we need to do that I think I’ve recruited 30 high quality people in this year alone. One of the benefits of joining Cowi is it has a far greater reach in terms of attracting staff. “Donaldson’s was a brand leader in terms of tunnelling design and geotechnics, but the ability to take a larger chunk of projects, as well as the name, is helping us in attracting staff. So that in itself will help us to reach our targets in 2020, also the numbers of staff that we need to employ to double in size is not astronomical. Part of that doubling is also having a more profitable business. Having more control, being at the top table gives us more control over our financial destiny.”

A principle challenge for this target according to Sloan is the threat to free movement of people posed by the British exit from the European Union.

“I think we have a concern over our ability to move staff around, concern over the degree of nervousness over the recent words and comments coming out of the Conservative Party Conference in relation to the free movement of people is of real risk to the UK industry. We need highly skilled engineers to come to the UK because we’re not producing enough on our own. If all the projects that [are planned for the UK] go ahead, they are obviously all concurrent, and we have a shortage of engineers in the UK. And I simply cannot see how, if we restrict movement of people in the UK, we are going to be able to service these large contracts [as a country]”



**Andy Sloan**

Andy Sloan joined Donaldson Associates 20 years ago and joined the board two years later. This was after a short stint with W.A. Fairhurst & Partners in Glasgow, Scotland, during which he spent six months seconded to Cowi working on the Copenhagen Metro project. Prior to that he spent 10 years at Golder Associates based in Maidenhead, west of London. At Golder Associates he worked on mining, tunnelling and geotechnical projects all over the world.

He says that the period with Golder

Associates was full of cutting edge hard rock tunnelling, but not without interesting soft tunnelling work, adding “I was very fortunate to start out with that much diversity”.

Sloan earned his first degree in geology then went on to do engineering geology. He says that he was always on the numerical side of the subject focusing on the mathematics and mechanics.

Additionally, for four years Sloan was a scientific advisor to the UK government on the Committee for Radioactive Waste Management. In this role he advised on underground matters.



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# OH MIA BELLA MADONNINA

Paola De Pascali visited sites of Milan Metro Line 4, which will cross the city from West to East along the old town centre and Roman ruins



50m-long stations will also be shorter than the 110m stations on lines M1, M2 and M3. The compact dimensions of the structures, especially in the stations, means that construction work on the line can be carried out more easily and with less impact.

### MECHANISED TUNNELLING

Six EPBMs will be used to excavate the M4 project. Two are from NFM with a diameter of 9.15m and four are from Herrenknecht with diameters of 6.36m and 6.5m. Two Herrenknecht TBMs are currently working on the East side.

The final lining of the tunnel will be made of precast segments. The ring for the 6.3m-diameter tunnels comprises six segments in a 5 + 1 key configuration with a thickness of 280mm. The 9.15m tunnels consist of a seven segment 6 + 1 keystone ring with a thickness of 350mm.

"For the TBMs with a 6.36m diameter, a 3.85m<sup>3</sup> of grouting is required to get a complete filling of concrete between the excavation and lining extrados," says Stefano Gazzola, Rocksoil's M4 project manager. "During excavation, data from the TBMs is available and compared to expected values. Grouting is being used to protect buildings and improve soil stiffness, particularly in areas with low overburden or structures of historical significance. So far, ground injections are expected in up to four locations and they have been designed to be made from the surface."

The segments are equipped with EPDM gaskets and are assembled with longitudinal mechanical dowels. The maximum advance thrust is 42,500KN for

**Above: The Sereni shaft is excavated in an open cut and it will be used as emergency exit and fire service access**

**T**HE M4 LINE OR Blue Line is an ongoing project to improve Milan's transport system and interconnection with the underground and the suburban rail network. After excavating underneath Milan's suburbs, TBMs are now working in the city centre, passing under highly populated areas and existing buildings. Excavation of the first drive of the running tunnels began from Linate station on 4 April 2014. On 11 November 2014, the TBM on the next drive reached the Forlanini FS station, completing the installation of approximately 2,370 rings of precast segments. At the end of November, TBMs started working on the East side of the M4 route, while the opposite side will be excavated in 2017. In 2018 TBMs will excavate the old town centre, carefully crossing some archaeological sites.

The M4 metro line was designed by Rocksoil, which provided data planning and analysis of the underground and civil works. The total value is EUR 1.8bn (USD 1.9bn) and will be mainly funded by the "MetroBlu" consortium, which is composed of Astaldi and Salini-Impregilo. The project involves the design and construction of two single-track tunnels, one in each direction, with 21 stations, 30 associated structures and a depot/workshop.

The 15km-long M4 will cross Milan from west to east passing south of the old town up to Linate Airport. The new line will be a fully automated light rail system, driverless, and with automatic platform doors and a CBTC (Communication Based Train Control) signalling system. The trains will be 50m long, considerably shorter than rolling stock in circulation today. The

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



the 6.36m diameter TBMs with 32 jacks and 82,000 KN for the 9.15m diameter TBMs with 38 jacks.

"The 6.36m TBM will be used for the sections from Manufatto Ronchetto, placed in the San Cristoforo area, to the Parco Solari station, and from Linate Airport to the Tricolore station," says Davide Fraccaroli, M4 TBM manager. "The 9.15m TBM will be used for the section from the Parco Solari to the Tricolore station."

Gatti explains, "The 9.15m machine will be used in the historic centre in order to enable the installation of the station platforms directly inside the inner contour of the tunnel in segments. It allows us to significantly reduce the impact on existing structures compared to the use of conventional tunnelling methods."

To place deep stations in the historical part of the alignment, a central shaft will be excavated at a depth of up to approximately 35m and transverse (outward) dimensions limited to approximately 10m. This central shaft will be used as a permanent access. Outside this, running tunnels are built using the 9.15m TBM, which provides sufficient width to accommodate station platforms within the bore. The connecting bypass between the station shaft and the platforms will be excavated after the soil has been grouted from the ground level with the continual use of cement and silicate mixes.

The open excavation method will be used for stations that are generally at depths of about 15m, while the station in the old town centre will reach depths of approximately 26 and 30m because of a higher overburden. Reinforced concrete diaphragm walls will support the open bottom-up method. In some areas a top-down method will be also used to cast immediately the top roof and reduce impact on urban areas.

One of the project's main challenges is working in highly-populated areas and in the historical centre of the city.

"We carefully assess any possible disturbance related to existing structures such as sewerage systems, water pipes, phone and gas cables, and so on. We also pay attention to the potential impact of works on existing roads and road traffic," says Gatti. "In order to find the best traffic solutions, the local Council may require diversions or alternative routes for buses or cars. Of course, each stage needs to follow such requests, which come from a specific site area."

#### ARCHAEOLOGY

The presence of archaeological sites has presented challenges as the majority of



**Above: The M4 route among other lines in Milan**

M4 stations are located in the historical city centre, which includes Roman ruins and buildings.

"For example, Vetra Station will be located near to the Saint Lawrence Church with the famous Roman columns," says Gatti.

To identify the grade of archaeological risk, archaeological surveys were carried out along the M4 route between 2008 and 2009, paying attention to the Cerchia dei Navigli ('Ring of Canals') area, the historical centre of the city. The cultural heritage department approved the project on condition that archaeologists can constantly monitor excavation works as the TBMs advance stroke by stroke. Excavations at the depth of 4m will be carefully performed in order to look for archaeological findings.

An analysis of disturbance to buildings caused by excavations has been carried out in two main steps. The first used subsidence theory and mathematical formulas to analyse surface settlements as a result of tunnel excavation. Thanks to this calculation, as Gazzola explains, it's also possible to include the effects of deep station excavation. "Through this process we can estimate a building's settlement, and strain, and calculate a damage class," says Gazzola. "Considering a building's state of repair, support material and year of construction, there are reference tables to reach a primary acknowledgment of the effects on each building."

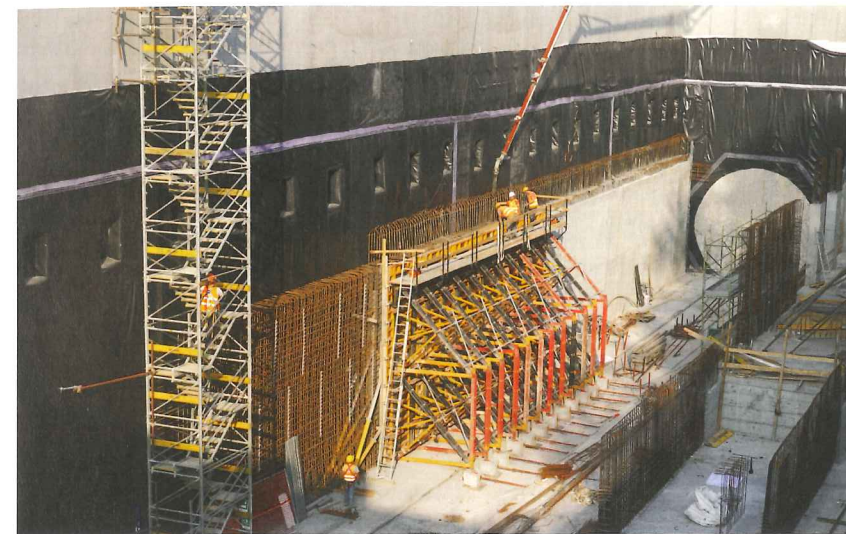
The second step was to evaluate if it was necessary to carry out numerical analysis by using various FEM and FDM software. That meant the opportunity to get a more accurate settlement calculation, which also checks the presence of the building and its stiffness. 3D FEM models for buildings could be also

#### Geological conditions

"From a lithological point of view, the area under excavation belongs to the 'fluvial glacial Wurm' unity with approximately 70m of thickness," says Gazzola. "It consists of most gravelly and sandy soils, which were deposited during the various phases of Pleistocene. The granulometry is mostly gravelly and silty and sometimes weakly silty."

As with all Milan's territory, the new metro is located in a lowland zone, occupied and modelled during the Pleistocene era by different glacial phases. Especially on recession phases, debris from the Alps was deposited and then modelled by rivers and waters.

During this process, a sedimentary series has been formed, constituted by a rock substrate and then by various layers, until to the most superficial unity (fluvial glacial Wurm), which interests these works.



**Above: Casting operations of at Dateo station. The formwork structure can be seen (right side) and steel reinforcements (left side, near service stairs)**

implemented in addition to a possible estimation of the "damage class".

"After carrying out these two different analyses, we are able to evaluate if grouting is necessary to prevent building settlements that have been considered to be critical," Gatti adds. "Consolidation works mainly consist of improving soil stiffness with concrete injections at various pressures. With deep station excavation, retaining structures, such as micro pile walls or reinforced concrete diaphragm walls, are used to reduce building settlement."

"A fundamental aspect of the tunnel construction in urban areas is the control of subsidence induced by excavation through a monitoring system," Gatti says.

"Monitoring during excavation is undertaken using settlement gauges set up approximately every 100 or 150m along the route at ground level."

"From the accumulated data we can compare theoretical and real results and calculate real volume loss caused by tunnel excavation. During the first 3.3km of excavation from Linate Airport to Forlanini Railway Station settlements have been on acceptable levels and close to expected values, with a ground loss of 0.5-0.7 per cent of tunnel excavation. It has to be noted that the first part of the track is located mainly in a suburban area without many buildings. Ground level settlements have been considered acceptable even where, in some cases, they were over predicted values."

For buildings' settlements operation the threshold is between 25 and 30mm, Gazzola says, but each case is carefully analysed as necessary. When real settlements exceed the calculation values a detailed explanation is usually provided, including analysis of the TBM's data, specifically the pressure values and the chamber-excavation.

The monitoring programme also consists of strain gauges positioned inside concrete segments in order to control internal forces acting in the final lining. One ring is equipped with instrumentation every kilometre, increasing for particular areas of interest.

For buildings near station excavation, a specific monitoring programme has been provided considering also interaction with tunnel excavations where necessary. On buildings, settlement gauges and instrumentation for inclination measurement are provided. In order to get information on foundation settlements, displacements at deeper levels can also be investigated with specific inclinometer instruments.

If ground movements increase in a way not predicted by

calculations, measurements are intensified (two for each day) in order to clarify the situation.

"To control varying settlements as indicated by monitoring data, the excavation's chamber pressures and both pressure and quantity of conditioning grouting are revised," Fraccaroli says.

"During the design of TBM working pressures, acting inside the excavation chamber, we considered any possible interferences with the existing underground infrastructures such as the Milan Passante railway, which crosses the city of Milan from the North to West side," Gatti says. "In order to avoid heave of the existing tunnel due to low cover separating the two, a lower working pressure will be used and a monitoring system on the existing railway will be carried out with settlements and slant measurements. The railway manager has also provided the limit values compliant with the operation of trains."

#### SERENI SHAFT

"The Pozzo Sereni is a shaft excavated in open-work, carrying out lateral support works which are reinforced concrete diaphragms. It is located near the Forlanini Station and it will be used as emergency exit and fire fighters' access. At the moment it is the launching shaft for the TBMs in the east side. Pulling together these diaphragms, we obtained a support area where it's possible to excavate," Gatti says.

"Working with a high aquifer, it's essential to do concrete injections under the level of the final dig. This waterproof barrier let us excavate without any problems, avoiding water inflow with flowing ground from the excavation."

The TBM's conveyor belt is vertically oriented to save space on site. Fraccaroli adds: "This 100m-long TBM is not fully assembled because we are working in



**Below: The complete tunnel at the bottom of Forlanini FS railway**



Above: TBM breakthrough

confined spaces. Thus, the back-ups are temporarily placed in an open-air area and when the TBM advances, they are lowered down the shaft."

The TBM's average progress has been 20m per day, working in what is a high-density area. "For example, we experienced this average for the section from Linate airport until the Sereni shaft, achieving some peaks of 35m per day, as well," says Fraccaroli.

#### FORLANINI FS STATION

The tunnel beneath of Forlanini FS railway has been completed, including the platforms and all the civic works.

On its route it meets the railway at several points and each stop is 600m apart.

"In these locations we have adopted a system of cladding with precast concrete segments and it has been designed on universal ring logic," Gatti says. "This allows us to navigate bends at 180m of planimetric radius. These precast concrete segments have longitudinal connections that prevent adjacent rings disconnecting.

"It's important to pay attention to the second tube's excavation to consider the ground movement caused by the first tube's excavation. During the second tube's excavation higher settlement may be detected as generally happens."

Moving from east to west the next stop after Forlanini FS is Argonne.

"Here there is an open-air excavation, where a team specialising in waterproofing is working to place the PVC membrane around the station before casting the internal reinforced concrete lining. However, the membrane is not placed in the space where TBMs break-in the station.

"The retaining wall of this area is reinforced through fibreglass structural elements to be easily cut by the TBM's cutterhead," Gatti says.

#### DATEO STATION

"A team specialised in grouting is currently working at the Dateo station at the level of the acquifer (14m down from ground level) to perform the bottom plug and to protect the future excavation from water inflow. The Dateo station requires grouting plug because the excavation will reach the depth of 32m," Gatti explains. "The grouting is performed by PVC tubes, equipped with manchette valves."

Gatti adds: "We use a mix of water and concrete in addition to waterproof materials such as silicate. The combination of these materials not only allows a good permeability on the ground, but also a waterproofing to avoid leakage of water into the excavation. After the perforation, we can drop tubes to cement them to the ground with the concrete mix. There are also valves at some points to inject the mixture of materials in some empty intergranular spaces. Once they are filled, the flow of water can't pass through inside them.

"Designers usually identify the right distance between these PVC tubes to ensure the efficiency of this grouting," Gatti says. "The fundamental parameters also include pressures and the quantity of mixtures so that waterproofing can be extended on the whole face."

#### SUSTAINABILITY PLANS

The Blue Line is being carried out in full compliance with sustainability and environmental criteria. Thanks to this new line, it will be possible to significantly reduce traffic congestion and air pollution, improving the quality of life in Milan.

The planning of surface sites will be compliant to ISO 14001, a series of environmental management standards, which includes a waste plan and noise control, and each activity to reduce the environmental impact.

According to the Environmental Monitoring Plan it will also be possible to analyse the potential effects of the M4 on the surrounding environment. Controls will include measurements of biological, chemical and physical parameters relating to the construction works. Results based on monitoring will drive the main operations in terms of possible adjustments, updates and running changes. The Environmental Monitoring Plan will also check the hydro-environment, noise and air pollution and the state of vegetation.

"For example, an acoustic restriction to 50dB (measured near the work site) has to be observed in the city centre," says Gazzola. "Each zone of the city has been mapped with a specific limit on acoustic pollution" 🌐

Below: From the right Martino Gatti, Renzo Bindi, Davide Fraccaroli and Mauro Orecchia, engineers on the project



## TUNNELS No. 8/8a IN SOCHI (RUSSIA)

Face: 220 m<sup>2</sup>  
Ground: clayey flysch (Voronzoff overthrust zone)

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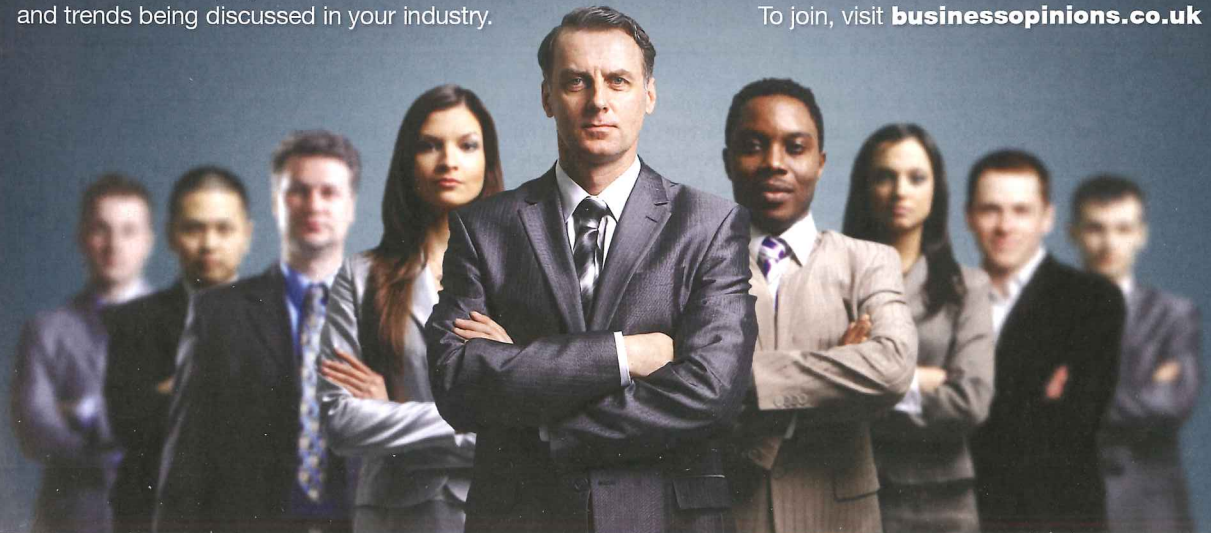
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# TWO TRIBES

The first on-site comparison between NATM and ADECO-RS during construction of the "Dubler Kurortnogo prospekta" tunnels in Sochi (Russia)

**Nikolai Batyrev**

Transstroytunnel, Moscow, Russia

## Adeco-RS methodology description

The main feature of the Analysis of Controlled Deformation in Rock and Soils (ADECO-RS) design and construction approach for tunnels is that the design engineer focuses primarily on the deformation response of the ground to the action of excavation. This deformation response is first analysed and predicted, during the design stage, using a variety of instruments (full scale and laboratory tests, mathematical models, and so on), then it is controlled, during the construction stage (clearly separated and subsequent to the design stage) by using appropriate stabilisation measures.

As opposed to past approaches, that only considered deformation behind the face (convergence) and operated solely within the cavity, downstream the excavation face, with bolts, ribs, shotcrete and somewhat temporary inverts, in the mistaken belief that any problem could be solved by partitioning the face, the ADECO-RS approach investigates the deformation response thoroughly, right from its onset where it starts ahead of the excavation face and then behind the face (extrusion, pre-convergence and convergence). As a consequence, the approach controls the potential instability of the core-face and of the cavity advancing by using the core of ground ahead of the face (appropriately improved beforehand, when necessary, with stabilisation measures) as a structural element to stabilise the tunnel during the excavation and construction stages.

**T**HE WINTER OLYMPICS IN Sochi, Russia, that took place from 7-23 February 2014 were marked by major investments aimed at overcoming the city's lack of infrastructure and to improve its transport network. One of these projects is the new Sochi motorway, also known as "The alternative to the Kurortnyi road", which runs parallel to the Black Sea and makes it possible to reach the Olympic sites and the Adler airport without having to cross the city. Construction of the new artery, of decisive and strategic importance, required the construction of eight double-bore natural tunnels, as well as open-cut sections, embankments and bridges for a total length of 16km. Due to the difficulties caused by the nature of the ground and the short amount of time available for construction, Russia decided to maximise productivity and minimise risk by adopting the ADECO-RS approach

for the design and construction of the T8 and T8A tunnels (these two being the longest and most complex of the motorway).

This approach was judged to have been reliable during the construction of the new Bologna-Florence high-speed railway. This called for more than 100km of tunnelling in similar ground to that in Sochi. The T8 and T8A tunnels are therefore of interest given that other tunnels required for the same motorway by-pass (facing similar ground conditions, although shorter and perhaps less difficult overall) have been excavated by NATM, which is well-established in the Russian tunnelling culture. For the first time therefore, the author is in position to work out a comparison between the two methods based on real data.

## GENERAL CHARACTERISTICS OF THE PROJECT

The new Sochi bypass presents two separate carriageways; each with two lanes in each direction, designed for speeds of 120km/h. Construction required the excavation of a series of tunnels (Figure 2). The T8 and T8A tunnels, excavated by using ADECO-RS, in addition of being longer than the others, are of a more significant cross sectional area, ranging from 120 to 220m<sup>2</sup> (Figure 3). It is noted that the 220m<sup>2</sup> cross-section is in the proximity of the North Portal (in a landslide zone) where a

Photo:  
Caucasus  
Mountains,  
Sochi, Russia

junction of the new with the old road network is located. Another point of relevance is the lower cover of the tunnels, which were excavated in heavily inhabited areas as shown in Figure 4.

## GEOLOGY AND GEOTECHNICAL ASPECTS

Sochi is located at the western slope of the Caucasus Mountains, a chain that stretches for around 1,100 – 1,200km between the Black sea and the Caspian Sea. Like the Italian Alps, the mountain system formed during the Cenozoic era – around 25 million years ago – following the collision between the Arabian plate and Eurasian plate. In this context, the Sochi motorway by-pass is located along the shore of the Black Sea, which is characteristic for the hilly and heavily vegetated countryside.

As illustrated in the longitudinal geological profile of Figure 5, the T8 and

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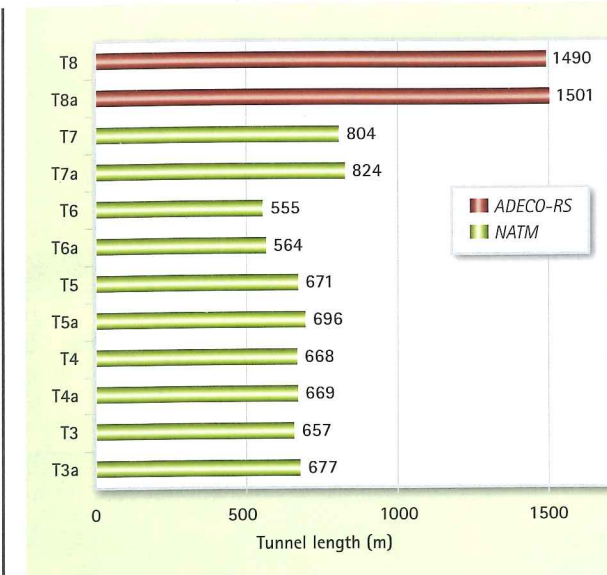
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Right: Figure 1, The location of Sochi in Russia



Left: Figure 2, Tunnels along the Sochi motorway bypass divided by excavation methodology

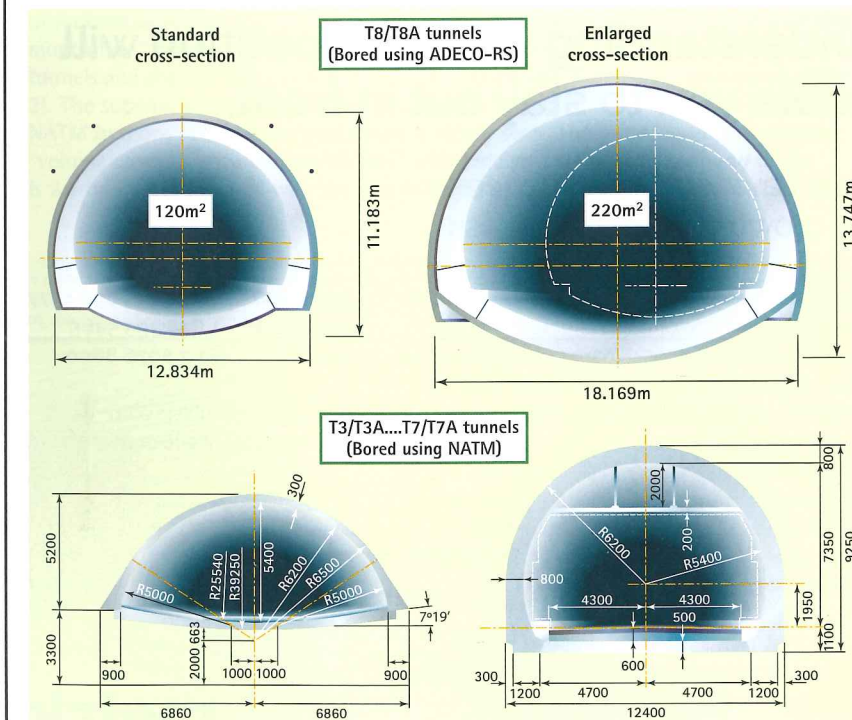
Below: Figure 3, The T8/T8a tunnels (bored full face using the ADECO-RS approach) measure excavation sizes between 120m<sup>2</sup> and 220m<sup>2</sup>, while the other tunnels (bored half face using the NATM) measure excavation sizes just equal to 113-115m<sup>2</sup>

T8A tunnels cross the Sochi Formation, composed of clay-stones and silty-clays, and the Mamai Formation, with marly-flysch with a scaly structure. The two formations are intersected by faults. Also to be highlighted is the presence of colluvial-eluvial sedimentary covers met near the tunnel portals and in low overburden zones, where also present are active landslides.

A very dreaded 'Voronozoff overthrust zone' is located near the northern portal.

### DESIGN ASPECTS OF THE T8 AND T8A TUNNELS

In line with the predictions based on ADECO-RS, the T8 and T8A tunnels were excavated along the entire length instable conditions in the short term or unstable core-face conditions (type "B" and "C" stress-strain behaviour categories). As shown in Figure 6, excavation was full face using the necessary protective and/or reinforcing measures of the "core-face" and by



keeping the kickers and the invert of the final tunnel lining in close proximity of the advancing tunnel face (less than one diameter).

It is noted that in all cases, for the cross sections where the core-face reinforcement could be avoided, this last stabilising measure has always been adopted due to the presence of a significant in situ horizontal stress component. At the landsliding north portal, the C2W section type with an invert strut was adopted in order to limit deformation to the highest level. As regards to types in section C, alongside reinforcement of the core-face by means of fibre-glass structures, the figure highlights the treatment along its outline which was carried out by operating injections through fibre-glass structures equipped with manchette valves. Figure 7 gives a view of the tunnel face with the stabilization measures completed.

### TUNNELS T8 AND T8A: PRODUCTIONS

Productions and construction times were affected by:

- The necessary time (at least six months) to acquire experience and generally become familiar with the ADECO-RS approach (which had never been used before in Russia);
- Logistical difficulties due to transportation of construction material, machinery and necessary spare parts to the site. The enormous investments allocated towards construction in Sochi led to an incredibly high concentration and volume of demand for raw materials. The transportation and rail systems were not initially capable of supporting such a massive movement of material; furthermore, the winter weather conditions made it difficult for ships to dock, thus invalidating sea delivery as well.

This, obviously, created significant difficulties towards the efficient application of a highly industrial system

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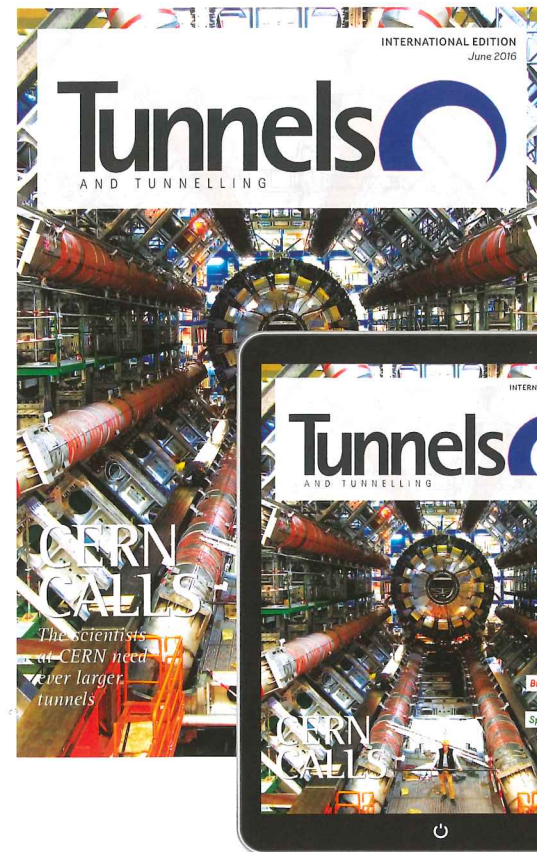
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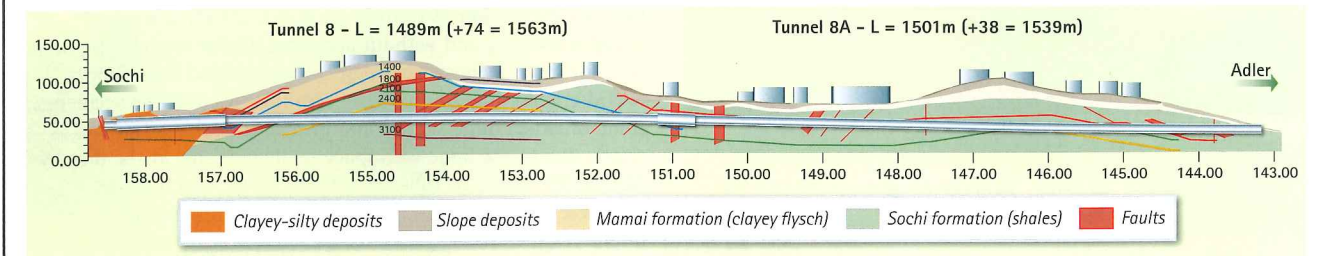
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such as the ADECO-RS. Despite this, the T8 and T8A tunnels were excavated with a rate of excavation of 40 to 90m per month, except when under-passing the landslide zone at the North Portal, where the same rate became equal to 20m per month, also due to the large tunnel cross section adopted (220m<sup>2</sup>). It is noteworthy that, independent of the difficulties of various kinds met in order to getting well organized and to adopt the novel and, for the Country, yet unknown, technologies which characterize the ADECO-RS approach, the productivity of the excavation process soon became as expected, also due to the gradually gained experience in the application of the approach by the Contractor.

### COMPARISON BETWEEN ADECO-RS AND NATM

#### Production

It is of interest to draw attention to Figure 8 where the "volume of rock excavated/month/face" and "metre of completed tunnel/month/face" ratios are shown for the T8/T8A (ADECO-RS) tunnels and the T7, T7A, ..., T3, T3A (NATM) tunnels (see Figure 2). The superior performance of ADECO-RS with respect to NATM in terms of these two parameters is clearly seen. The "volume of rock excavated/month/face" with the first approach is 2.4 times that attained with the second approach; similarly,

**Top: Figure 4, Tunnels T8 and T8A, in an urban area, were the longest and most complex of the motorway**

**Above: Figure 5, Geological profile of the T8 and T8A tunnels (fault areas in red)**

**Below: Figure 6, Typical cross section with the stabilisation measures of the "core" and of the tunnel contour ahead of the advancing face**

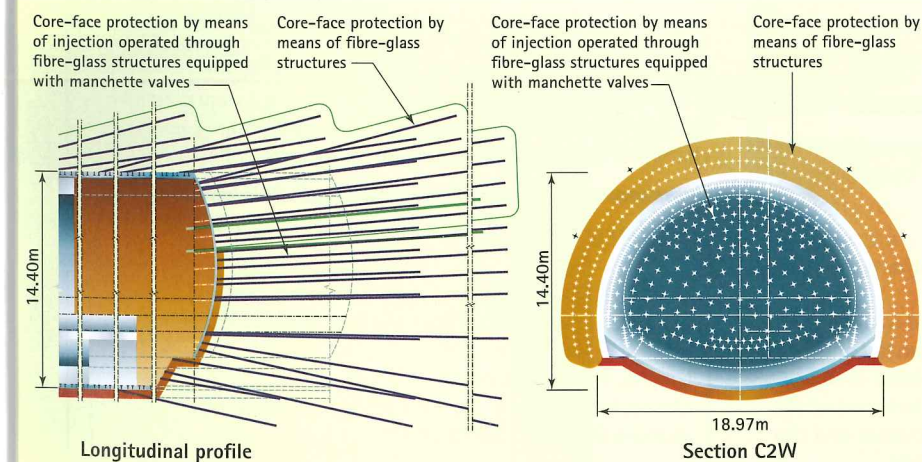
the "metre of completed tunnel/month/face" is 40 per cent greater for ADECO-RS with respect to NATM.

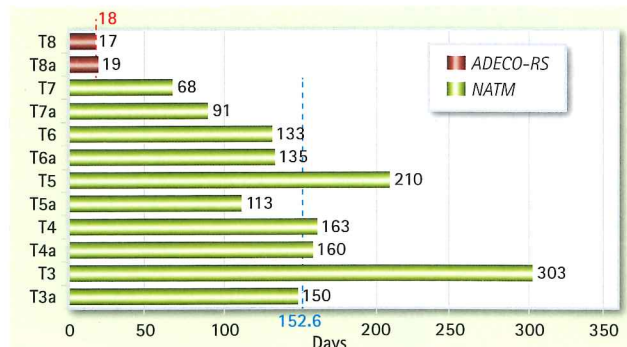
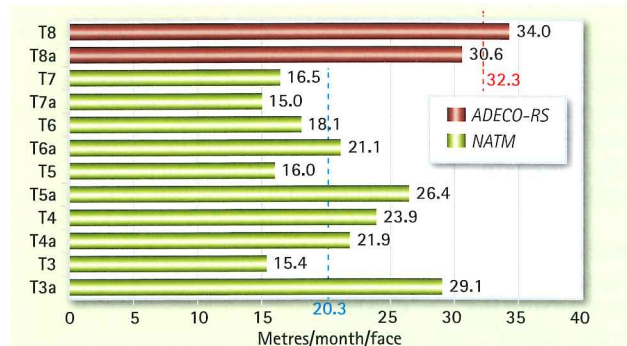
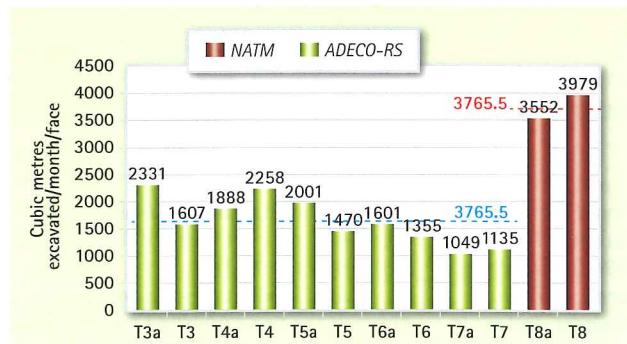
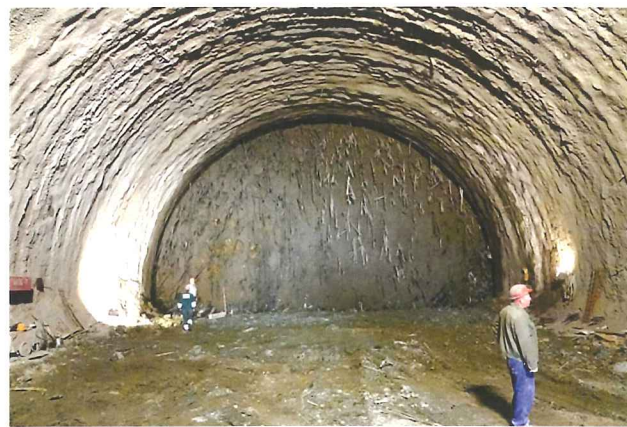
An additional interesting comparison between the two tunnelling approaches is possible by plotting, as shown in Figure 9, the time (days) between the breakthrough in a tunnel and the time elapsed before the final lining was installed, i.e. tunnel stability and safety were reached. It is clear that the ADECO-RS, for its own nature, is characterised by the very short time (three weeks approximately) of the final lining installation with respect to the NATM (from 10 weeks minimum to 43 weeks maximum).

#### Costs

It would seem reasonable to suppose that the full-face excavation of a tunnel with concomitant stabilisation measures applied to the core, typical for the ADECO-RS tunnels excavated in difficult ground, is more costly. The experience gained in Sochi shows that it is not so: NATM was generally more expensive because of the higher cost of workforce and machinery (NATM employs on average one and a half times more manpower than ADECO-RS and a large number of small machines against a few, large and powerful machines used by ADECO-RS).

Furthermore, taking into consideration the production data shown in Figure 8 the highest values of ADECO-RS comparing to NATM are more than evident. The difference of production in terms of average percentage is in the order of 30 per cent with a minimum guaranteed value of 5 per cent. This is a direct consequence of the job site organization and this means a sharp





From top to bottom: Fig 7, View of the tunnel face showing the core-face stabilisation measures; Fig 8a and b - Comparison of ADECO-RS and NATM in the Sochi tunnels in terms of "cubic meter excavated/month/face" (above) and meter/month/face completed (below); Fig 9, Comparison of ADECO-RS and NATM in terms of the time (days) between the breakthrough in a tunnel and the time elapsed before the final lining is installed

reduction in terms of construction times and, as a consequence, costs (site active for fewer days). If you add to this the high industrialization of the tunnel construction guaranteed, ADECO-RS appear without doubt more advantageous also with reference to the costs.

**Safety**

Regarding safety, the objective data collected during excavation of the tunnels for the new motorway by-pass of Sochi has shown the following: although the Russian company and designers were experienced in NATM rather than ADECO-RS, the full-face excavation of tunnels using ADECO-RS proceeded straightforwardly and without accidents. Unfortunately, the same was not true for those carried out in partitioned face using NATM criteria. Indeed, in these cases there were many accidents, some of which quite serious and involving workers. This fact is clearly due to the large workspace made available at the face by ADECO-RS thanks to full-face advancement, which allows complete mechanization of excavation: the presence of unprotected workers in the face area is practically excluded. Another reason is that little time incurs from the moment of excavation to the set of first-phase and final linings, thus stopping stress from evolving to the point of developing serious manifestations of instability. Indeed, continuous monitoring the stress-strain state of the advance core was of great importance, anticipating and blocking any risky situation before it occurred.

**CONCLUSIONS**

The recent excavation of Sochi motorway tunnels was of particular interest given that two of them (T8 and T8A) have been excavated using the ADECO-RS approach, whereas the remaining ones (T7, T7a, ..., T3, T3a) have been completed by adopting the NATM method. This has allowed the author to make a first straightforward comparison, under quite similar conditions, between the NATM and ADECO-RS design and construction methods.

It is the author's opinion that it has been shown that the ADECO-RS approach, above all when applied to tunnels in difficult ground conditions, as in the case of Sochi, when full face excavation with concomitant stabilization of the core-face takes place, offers significant advantages in terms of production rates that can be achieved, the shorter time needed for tunnel completion, the reduced man power needed at the face, the high industrialisation of the tunnel work, and the greater safety conditions obtained. Regarding safety, it is important to underline that during the construction of tunnels T8 and T8A not a single accident has occurred, in contrast to the other tunnels excavated using NATM where several injuries have been counted. The tunnels were completed before the agreed deadline and - which is very important - without incidents. This latter fact has had great response in Russia and has been recognised and decorated by the Ministry of Transport of the RF.

Introducing the ADECO-RS approach in Russia will certainly take time and will necessarily entail passing through a series of changes including amending building regulations

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# IMPERVIOUS INFRASTRUCTURE

Spray on waterproof membranes remain a niche market but when it comes to complex geometries and potential tunnel design the advantages are becoming more widely understood and accepted



Above: Crossrail Fisher Street Cavern

SINCE SPRAYED MEMBRANES WERE launched in 1996 there have been some good successes and a number of disasters," explains Ross Dimmock, managing director for Normet UK, manufacturers of the TamSeal 800 spray applied waterproof tunnel lining system. "The problem areas came from extremely wet tunnels where it wasn't appropriate to use these liners or where the tunnels were left to freeze before it was coated with concrete and where people hadn't done quality control checks prior to putting the secondary lining in place," he says. In short such "disasters" are avoidable and lessons are being learned from problems of the past.

Today he says that the market for these systems has improved although it remains a very small proportion of the waterproofing

## Bernadette Ballantyne

Bernadette is a freelance journalist and regular contributor to *Tunnels and Tunelling*



sector where sheet membranes still dominate. Complex geometries or cross passages on TBM bores are particular hot spots. "There is a small window where this is very useful and that is what we try to do," says Dimmock pointing to recently completed projects at Farringdon Station and Fisher Street on London's Crossrail where the TamSeal 800 product was used by the BAM Ferrovial Kier contracting joint venture to waterproof the crossover cavern, two ventilation tunnels and escalator shafts.

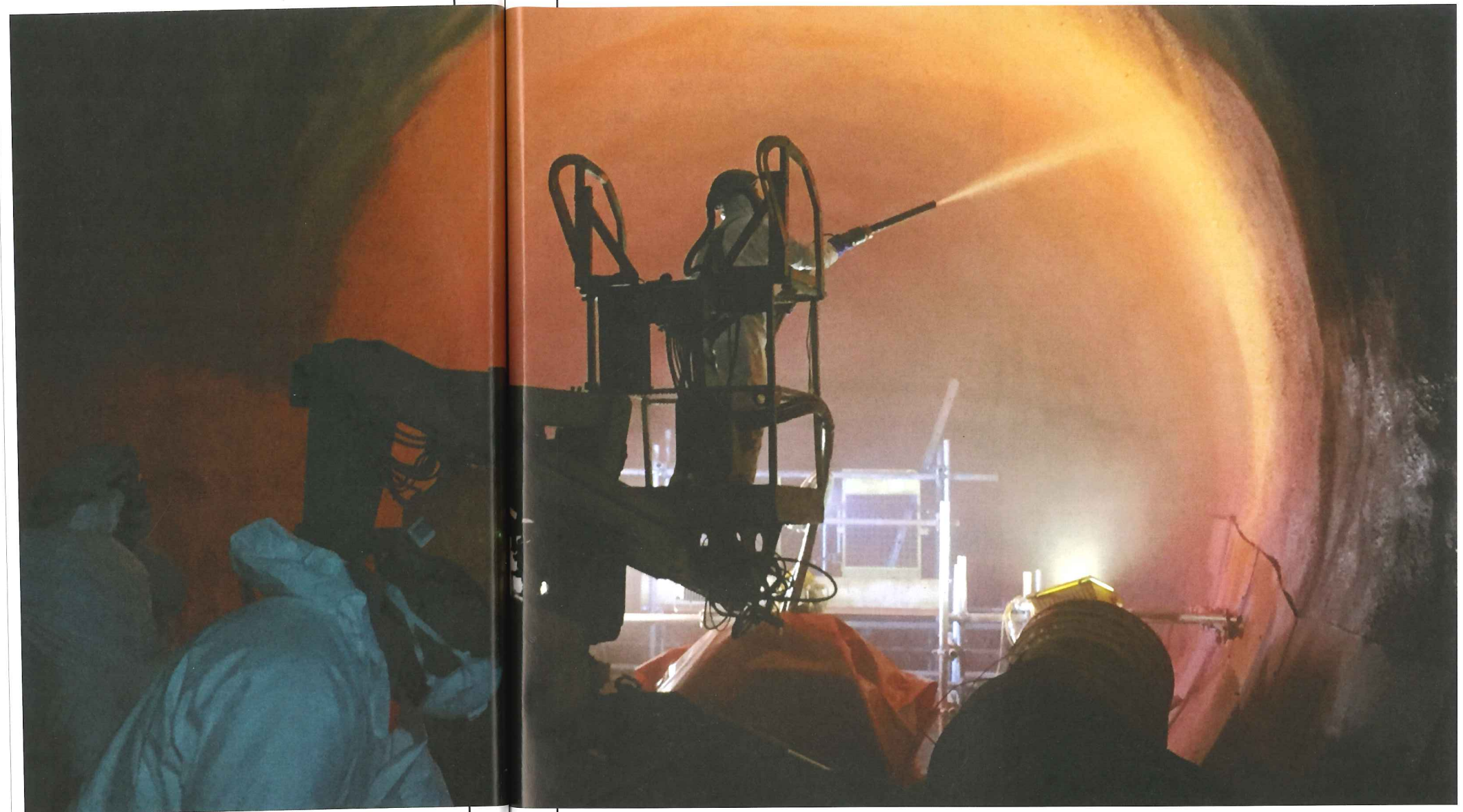
"The double-bonded spray applied membrane solution prevents the danger of water travelling down the shaft along the membrane and filling up the space behind the sheet membrane in the platform tunnels and loading and pressurizing the sheet membrane and secondary lining," explains Dimmock pointing out that PVC sheet membranes were used for the more uniform underground spaces. "A lot of people don't realise that if you have these bonded spray applied membranes they can't let water move and that was the key criteria for this project - to stop the water travelling down from the overlying water laden gravels through to the clays."

Just as importantly these bonded membranes can favourably change the structural characteristics of the tunnel lining. "If you can effectively connect the primary and secondary lining then you have what we call composite action and a researcher at Southampton University, Jiang Su, has recently modelled that behaviour to give the industry clues as to how to make the linings more efficient," says Dimmock, noting that the forthcoming contracts in London are

**Right: Crossrail Farringdon Station project**

**Below left: North Strathfield Rail Tunnel - Australia**

**Below right: Crossrail Fisher Street Cavern**



set to include this benefit in their design, where water pressure can be considered to act at the back of the primary linings, rather than inefficiently at the membrane interface. This wasn't possible on Crossrail.

"I was employed with Mott McDonald on development designs for Crossrail but we didn't have the knowledge or products in the market at that time but I'd say now, six to seven years on, we have the opportunity to and London Underground is very bold to allow the designers to consider it, and the linings there are more efficient, which is good. The client's design standards also prevented us from considering water pressure acting anywhere else other than the membrane interface, be it spray applied or sheet membrane."

The TamSeal 800 system uses co polymer dispersion based on ethylene vinyl acetate (EVA) technology, as does BASF's Masterseal 345, which is also used for tunnels and underground spaces. "EVA based membranes are robust and can be used on shotcrete and damp areas and you are not worried about condensation. We have done a lot of occupational health studies and it is quite safe," says Dimmock noting that recent advances in their formula are helping accelerate the curing process. "We have got a built in curing system in the product



so it is not just wholly reliant on evaporation and drying like in the old days. If it is humid that used to cause problems or it would just dry on the surface and now we want the curing right the way through the product so it has a built in chemical curing system that works when you spray it. It is activated straight away.”

Application is recommended as a two-stage approach with the first bright orange layer applied and left for an hour or two before the white top coat. Total thickness is between 3mm and 5mm depending on the substrate surface, and the degree of crack bridging required. No primer is required.

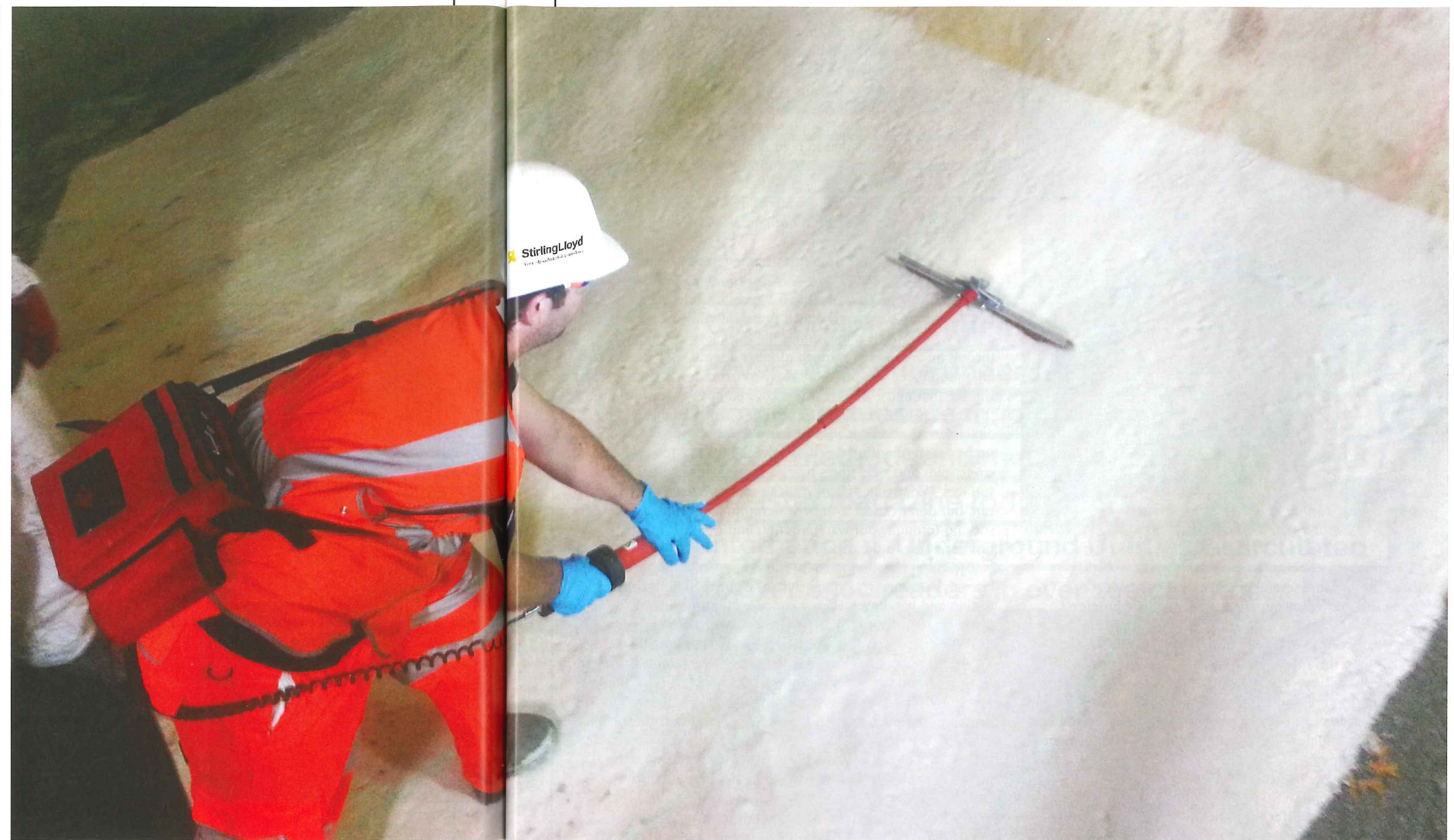
“The two layer approach covers all defects and is commonly used in other industries to ensure coverage. We saw that in waterproofing tests, not all of our membranes passed when we applied just one layer but when we applied two, we never had a problem.”

Thanks to the new formula Dimmock says that the membrane can be sprayed and walked over after 24 hours and ultimate cure time is around seven days.

Manual or robotic application is possible but the relatively high cost of robots means that most contractors stick to manual spraying with cherry pickers and lifting platforms to achieve the required height. Dimmock says application rates are similar in either case and 100m<sup>2</sup> per hour is the typical rate.

Another high profile project to successfully use sprayed membranes was the Hindhead Tunnel in Surrey, UK, where sprayed concrete lined tunnels and spray applied waterproofing was used for 1.8km of twin bore tunnel. Here BASF's Masterseal 345 was used and once again lessons have been learned for future applications. “We learned a lot about how we go about the concrete and the substrate and getting the boundary conditions for the membranes right and that is where the improvements have been,” says Karl Gunnar Holter, technical manager for underground construction at BASF. He says that these are important steps forward and that getting the boundary conditions right includes managing the evenness of the regulating layer, fibres in the regulating layer, crack width control, as well as interfaces with other structures that come later.

He says application speed for the Masterseal 345 system is between 50 and 80m<sup>2</sup> per hour and curing time is two to five days. Like the Tam Seal 800 system no primer is required and it gives the same potential benefit of composite action between the primary and secondary sprayed concrete linings



Manufacturers of Integritank HF argue that the ability to conduct in-situ testing of the entire lining gives it an advantage over other systems

**W**ATCHING TECHNICIANS RUNNING A 600mm wide brush head over the smooth white resin you would be forgiven for thinking that the team is cleaning a recently applied waterproof membrane. But most cleaning brushes don't come with alarms or flashing lights, nor are the bristles made of brass.

“We test the membrane with electricity. As the membrane is resin based it is an electrical insulator,” says Mike Harper, business development director, for infrastructure protection specialists Stirling Lloyd.

For 40 years the company has been applying its spray on waterproof membranes to bridges, buildings, immersed tube

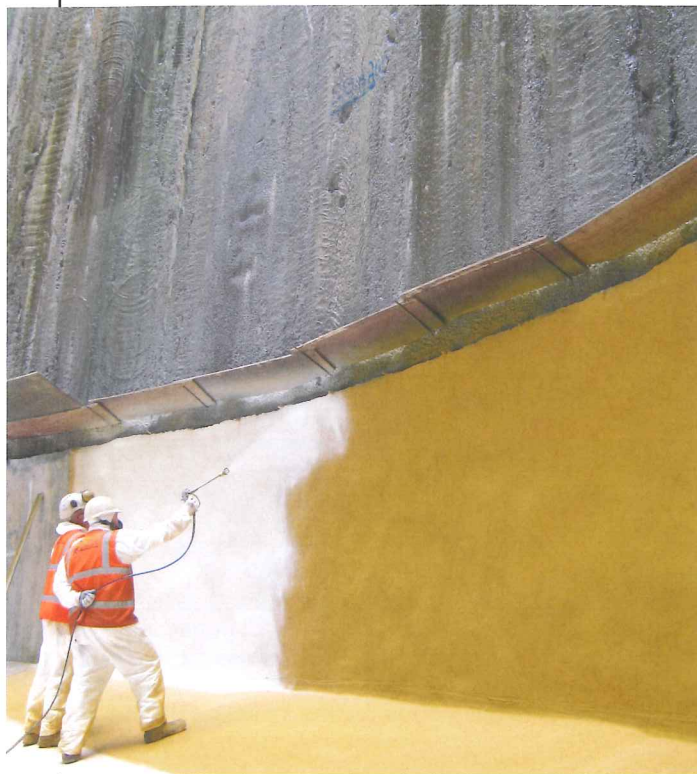
tunnels and other infrastructure and since 2000 it has been manufacturing the Integritank HF system specifically for use in confined spaces such as sprayed concrete lined (SCL) tunnels. “Once we have our membrane applied at the right thickness we run a detector head over the entire sprayed surface in 500mm wide strips. We apply quite a high voltage at low current and if there is a defect it will allow electricity to pass through the membrane. If the current flows you get a light and an alarm so you know that in that area there is a little defect and you can hone in to that area to get pinpoint accuracy,” he says.

In-situ electrical conductivity testing is not possible with membranes containing water, and Harper says this gives his system an advantage. “With a lot of tunnels water is controlled during construction but over time water will come back and finding out that the waterproofing membrane wasn't waterproof at all is no good a year down the line once you have turned off the pumps. So you need a way of testing the membrane as soon as you have installed it,” he says, pointing out that this is not possible for sheet membranes. “The industry saw the benefit of sprayed membranes in terms of better water tightness. Sheets are

*Above: The spark test being conducted on Integritank HF at Crossrail contract C510*

waterproof because they are usually tested in the factory site but once you have welded them on site you can't always test the welds. The more complex the project the more likely you are to get leaks. Projects like in London where there is complex geometry with the escalators and shafts and everything that we have got there you are more likely to get leaks with sheets so a sprayed membrane is the way to go,” says Harper.

What is more the bonds formed between the sprayed membrane and the primary and secondary shotcrete layers create a composite structure meaning that the primary lining can be considered load bearing for the final design – something which tunnel designers are already using to create more cost effective tunnel linings.



Although there are several major players in the sprayed membrane market Harper says his product is different. "The difference between us and just about everyone else in this marketplace is that our product hasn't got any water in it. So it is not waiting for evaporation or hydration of cement. It cures by chemical reaction and it would still cure if we sprayed it into water."

This means a very fast cure time for the acrylic based resin of 30 to 40 minutes. "It doesn't matter what the humidity in the tunnel is, you are ready to move on," he says.

Developing the Integritank HF product has taken time and it continues to evolve. "The products that we use on bridge decks and immersed tubes do have an odour to them and have a low flash point so neither are suitable in confined spaces. So we developed Integritank HF with the same resin technology but we have made it non-flammable. What we didn't do well enough is that it still had an odour to it. Not a huge odour but we found that when we were spraying trials in Whitechapel C510 the odour built up over time so we have gone away and refined it and taken the odour out. So we have taken out the two drawbacks, flammability and odour."

#### REFINED PROCESS

Stirling Lloyd recommends manual application for its system, which involves

a five-person team, two spraying the membrane, one person on the pump and two people on quality control. The first step is application of a primer to block any pores in the concrete which may still be outgassing as the concrete cures and the heat of hydration pushes air out of the concrete.

"If you spray on top of that there is a risk that the gas makes holes in the membrane. This primer is also a water based product and it is intended to hold damp substrates so rather than damp continuing to come through the wall you can spray on to the damp concrete and then that will set it and enable us to get the membrane over. If water is gushing through the wall you have to stop or divert it - nothing will stick to that regardless of what anyone says."

Following the primer the first 1.5mm layer of bright yellow membrane is applied, its bright colour is designed to highlight any defects. This is followed by the second white layer.

"We get up close and spray it professionally and we wet film dip as we go which is measuring the thickness in real time. If there is an area which is much rougher a robot can't see that so on a rough area you are more likely to get a defect. But a person will see that and ensure that it is covered and is measuring the thickness as he does. All of those things reduce the risk of having any defects," says Harper, explaining that both the ITA and BTS sprayed waterproofing specifications call for a regulating layer to cover voids and steel fibres that often pepper the 'as shot' surfaces. "Companies claim you can spray over steel fibres, you can, but don't expect it to be waterproof as you have steel fibres sticking through your waterproofing and creating a water path from one side to the other."

Typical application rates for the primer and both membrane layers is a 300m<sup>2</sup> section per shift of eight to 10 hours including testing and hand over. Harper concedes that this might sound slower than other systems, but claims that the longer curing time of these systems gives Integritank the overall advantage.

Recent projects include Thames Water's Beckton wastewater treatment works pumping station shaft and Shaft G on the Lee Tunnel. "Both of those needed to be dry and we have waterproofed the bases of them. What is important there is that they are 80m deep - 8 bar pressure in chalk so very permeable and there is plenty of water around and particularly for the pumping station shaft it needed to be dry because of the electrical equipment in there."

Having been tested up to 100 bar there is no danger of failure under hydrostatic pressure at tunnel depth. In fact so strong are the membranes that they are currently being considered for Canadian mine shafts up to 1,000m deep demonstrating that although this is a niche market new opportunities are emerging

**Above:** Technicians applying the final layer of Integritank HF on the Beckton Pumping station shaft on the Lee Tunnel project

**Right:** Wet film dipping to measure the thickness of the first layer of Integritank HF on Line B of the Buenos Aires metro in Argentina



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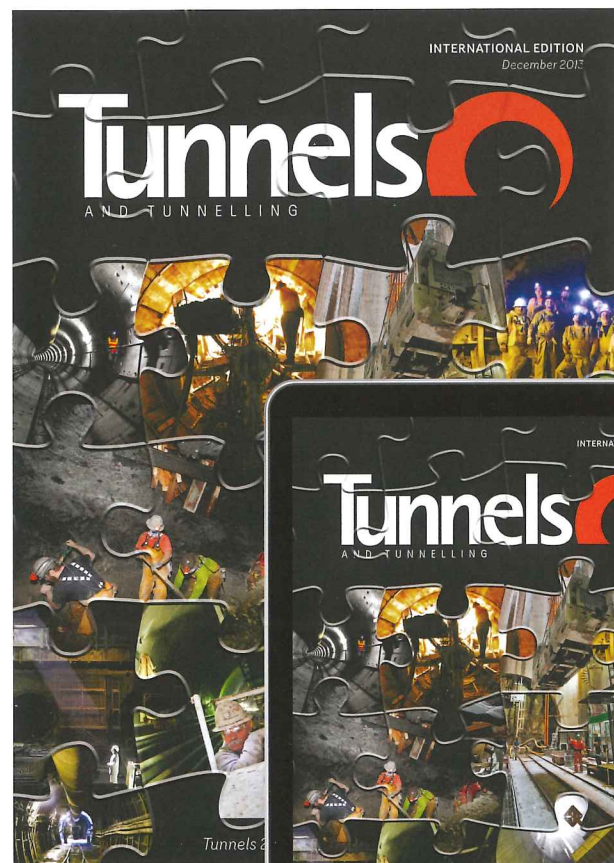
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## TO CAST OR NOT TO CAST

Vincent van de Vrie, discusses the merits of cast-in gaskets for precast concrete tunnel ring segments

**Vincent van de Vrie**

Vincent is a sales manager within Trelleborg's engineered products division



**T**RADITIONALLY, WHEN CONSTRUCTING A bored tunnel, the concrete tunnel segments used are fitted with rubber gaskets onsite. These are often secured in place using adhesive, to ensure a tight seal and cushioned fit between each segment. When in situ, both the seal and segment are placed under significant pressure, so it is imperative that they are able to perform to the highest standards in order to guarantee safety and performance.

By using a gasket that is precast into the tunnel segment during manufacture, installers can save time and money, as well as ensure a consistently accurate installation and a retained symmetry. However, it is important to take into account the design of the profile, as it can have a significant impact on the effectiveness and sealing quality of the gasket. Specifically, in the corners where the volume of rubber is generally the highest, it's vital that the profile design is properly thought out and fully tested, to prevent risk of cracking of the concrete or a leakage path at the corner position of the seal.

**THE RISKS ASSOCIATED WITH NON-CAST GASKETS**

For many tunnelling projects across the globe, tunnel segments are fitted with rubber gaskets onsite and secured using adhesive. But, it is not uncommon for those that use this method suffer time-consuming and cost-intensive repair work, which in extreme cases can exert negative effects on the outcome of a project.

This is because displacements can occur between segments if they are not placed in the exactly predetermined position during the on-site installation of the gasket. Displacements act either as an allowance for building tolerances or to help steerage, line and level during the

*Below: The Green Heart Tunnel in the Netherlands, fully lined*



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reduced applied load. This maintains a functional and watertight seal between segments despite ground movement and harsh wet and dry conditions.

With that in mind, it is vital that tunnel segment gaskets are precision engineered to meet the precise requirements of individual projects.

#### ADVANCE TUNNEL DESIGN WITH NEW CAST-IN-PROFILE

For bored tunnels, using a gasket which is precast into the tunnel segment during manufacture, removing the need for adhesive on installation can enable installers to save significant time and money.

This is because a cast-in gasket forges a superior bond connection with the segment to improve installation accuracy and eliminate the need for extra equipment. It is also more environmentally friendly and an altogether cleaner and safer process, as they eliminate solvent fumes and the presence of flammable materials. In fact, cleaning of the groove and correction of groove imperfections can be eliminated, optimising and shortening the production process.

Cast-in gaskets also provide a faster, cleaner and more accurate alternative for the manufacture of tunnel segments, integrating the gasket as part of the segment production process. Additionally, they prevent air entrapment within the solution while also helping to retain shape, symmetry and integrity when transported.

The profile is designed to fit into the groove within the mold and is incorporated into the production process. Once it is fitted, the mould is filled with concrete and the cast then becomes an integrated part of the final product. The size of the groove therefore has a major effect on the choice of gasket and its subsequent performance. This approach to tunnel segment gasket design also ensures increased water-tight performance, due to complex integration of the gasket into the concrete segment.

construction of the tunnel.

The purpose of the gasket is to seal to the required pressure at the maximum expected gap and displacement. However, as the size of the gap and / or displacement increases, the ability for a gasket to withstand water pressure decreases. Furthermore, the load transference areas diminish, which also leads to an increase in the stresses within the segment.

#### THE IMPORTANCE OF RUBBER QUALITY

The majority of gaskets for tunnel lining segments are made from extruded Ethylene Propylene Diene Rubber (EPDM) rubber. However, much depends not only on the quality of manufacture, but importantly the quality of the rubber.

Elastomeric tunnel segment gaskets, which are located in precast grooves encircling the mating faces of each segment, provide a secure rubber-to-rubber waterproof seal as soon as the segments are bolted together.

Therefore it is vital that the low compression set and stress relaxation values of the elastomeric compound used in their manufacture enable elastomeric tunnel segment gaskets to recover under



Top: Cast-in gaskets typically have a neater finish than glued methods  
Above: Segments fitted with cast-in gaskets heading to the face

#### THE IMPORTANCE OF CORRECT CORNER CONFIGURATION

One common concern across the industry when it comes to the performance of cast-in gaskets is the role of gasket corners – where the gasket material has to be mitred and vulcanized at the joint corner. This is because the vulcanizing material filling the holes in the gasket section can cause it to harden at the mitred corners.

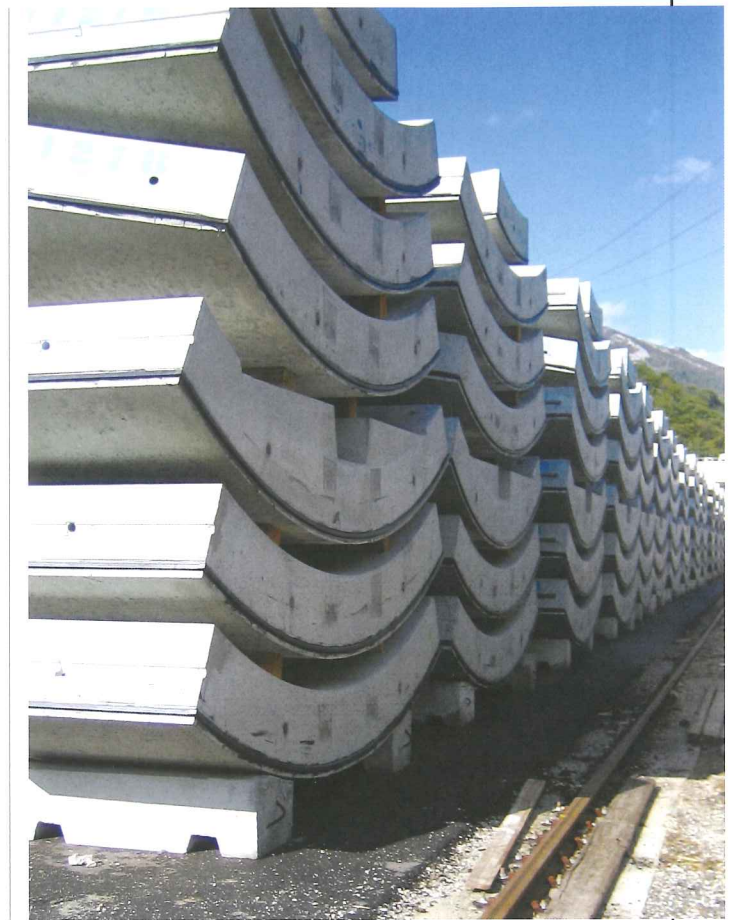
Associated with some 'rucking' of the gasket during segment installation, this can form a high point of the harder material, making the rubber incompressible. In turn, this makes the segments susceptible to cracking during installation, maximizing the potential for leaks.

Therefore, it is important that the gasket is designed so that it can be compressed but still provide effective sealing properties. For instance, too high a volume of rubber cannot be compressed and as a result the segment can be damaged, with broken corners or inserts that are pulled out. Another challenge is that the profile is not compressed effectively, resulting in holes forming between the seal and the concrete.

One solution is to enhance flexibility by ensuring a symmetrical design with an anchor at the corner position rather than straight sections, reducing the amount of rubber at corners. Finite Element Analysis (FEA) in the design process will help establish the maximum stress on the corners. The seals should then be tested for compression stiffness and water-tightness, to ensure they perform as required when in situ.

#### ENSURING THE RIGHT SOLUTION

It's clear that using a gasket which is precast into the tunnel segment during manufacture provides installers with many benefits, not least a consistently accurate installation with increased water-tight performance. However, it is vital that considerable thought is given to the design of the profile to ensure an efficient, watertight seal over the projected service life of the tunnel.



Top: Segments bound for a metro tunnel in St Petersburg  
Above: Construction of the Green Heart Tunnel, Netherlands

Therefore, finding a manufacturer with a proven track record for durability and reliability is crucial. Manufacturers need to be able to cater for the size and depth of the tunnel, as well as meet stringent pressure and testing requirements in order to eliminate costly remedial work to seal leaks after construction.

A manufacturer with in-house rubber compound technology can produce a tailored solution to meet project requirements and eliminate the chance of failure in situ. Additionally, it is important to turn to a supplier with the ability to perform extensive compression stiffness and water-tightness testing prior to installation.

Due to the complexity and monetary value of many of today's segmentally lined tunnel projects, the demand for engineering know-how behind their construction continues to increase. This also extends to elastomeric tunnel segment gaskets, as their performance has the ability to hinder or ensure the smooth running of a given project. Working with a global supplier with the right solutions, expertise and local support, means that installers can rest assured they are using high performance tunnel segment gaskets make projects run smoother

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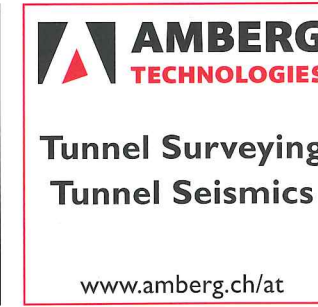
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# What's on

2016

## Bauma Conexpo India

12-15 December 2016

Delhi, India

The International Trade Fair for Construction Machinery, Building Material Machines, Mining Machines and Construction Vehicles—provides the construction industry in India with a professional platform for networking, investment and the exchange of ideas. [www.bcindia.com](http://www.bcindia.com)

2017

## The George A. Fox Conference

24 January 2017

New York City, USA

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

## 4th Arabian Tunnelling Conference

21-22 February 2017

Dubai, UAE

The ATC is the number one networking hub of Tunnelling and Underground Space experts and in the region. [www.soeuae.ae](http://www.soeuae.ae)

## First (Costa Rican) National Congress of Underground Works

21-22 February 2017

Dubai, UAE

This ITA-endorsed conference is to be the first hosted in Costa Rica. It is organised by ACROS, the Costa Rican underground works society. Further details are yet to be confirmed, please see the society's Facebook page for more information. [www.facebook.com/ctos.acg](http://www.facebook.com/ctos.acg)

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

3-6 April 2017

Sao Paulo, Brazil

The fourth edition of the Brazilian Congress of Tunnels and International Seminar: "Latin American Tunneling-LAT 2017", will take place in parallel to the 9th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground. [www.tuneis.com.br](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, and help delegates understand the technologies and techniques guiding the tunnelling industry. [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

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

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

## World Tunnel Congress 2017

9-16 June 2017

Bergen, Norway

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

[www.wtc2017.no](http://www.wtc2017.no)

## Geo M East 2017

15-19 July 2017

Sharm El-Sheik, Egypt

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

[www.geomeast2017.org](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.

[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.

[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.

[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 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)

## 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.

### Bond Street Station Upgrade Project

8 December 2016

This presentation will describe the challenges and solutions from the design stage through to the successful execution of tunnelling work for London Underground's Bond Street Station Upgrade project. From the perspective of the SCL designer and the Contractor working in a One Team environment, this presentation will look at maximising innovation and the utilisation of the latest technology. The project enabled SCL design boundaries to be pushed, and the development of a safe system of work by minimising the impact on infrastructure whilst at the same time optimising the excavation times to create necessary additional underground space. **Speakers:** Andreas Spiegl, principal tunnel engineer with Dr. Sauer & Partners *Please note that this event takes place on the second Thursday of December*

### The Harding Memorial Lecture: Tunnelling impact assessment for utility pipelines and tunnels

19 January 2017

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

### Joint BTS/MinSouth Meeting - The Alaskan Way Viaduct Replacement project (SR99)

9 February 2016

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

*Please note that this event takes place on the second Thursday of February*

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

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