

INTERNATIONAL EDITION

July 2016

# Tunnels

AND TUNNELLING



Exclusion zones

Silicosis

Faulted ground

## WARTIME TUNNELLING

*Tunnelling techniques and strategies  
used in times of conflict*

## THE LAMPS ARE GOING OUT

**Alex Conacher**

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



IN LIGHT OF THE RECENT VOTE by the British people demanding a split from the European Union, it is hard not to think about the history of the continent. Times are peaceful now, although it does not always seem that way, and looking back even a century reveals an unrecognisable political mess.

This month marks an important historical landmark as far as peace in Europe goes; it is exactly 100 years since the start of the Battle of the Somme.

For those who are not familiar, the Somme was a five-month engagement on the Western Front during World War One. Certainly for the British this battle has become a symbol of the conflict: an utterly unwinnable stalemate fought in the mud between two lines of trenches. Some 1.3 million people lost their lives to shellfire and to ruinous charges against machine gun emplacements.

It was a time in history when military technology had shifted to favour defensive tactics. The grand cavalry charges of the previous centuries had finally been abandoned just two years before, suicidal in the modern arena. Even artillery fire had limited effectiveness at breaking enemy lines. Although doubtless very effective at breaking body and mind.

Commanders had been desperately trying to find ways to break the deadlock. And one of the solutions was tunnelling.

At 7:28 a.m. on 1 July 1916, the first day of the Somme, eight large and 11 small carefully prepared

caches of explosives were set off underneath the German lines. The resulting devastation, the 'Lochnager mine', is one of the largest non-nuclear explosions of all time. An enormous crater formed and was promptly seized by the attacking forces.

Tunnelling did not end the war, and was far from an easy tactic for the workers involved. The conditions underground were horrific and cramped, and there was the ever-present danger of counter-mining operations collapsing the tunnel. It is an under-reported and scarcely remembered theatre of the war, although there is a memorial held every year on the 1 July held at the Lochnager mine site and schools still visit the crater.

To remedy that, and to commemorate the sacrifices of the underground soldiers of history, in this issue of the magazine we have the first of a two-part historical feature on military tunnelling, looking at the efforts of soldiers to excavate and support the tunnels using techniques such as 'clay kicking'. Written and researched by Myles O'Reilly, former chairman of the Tunnels and Tunnelling Editorial Advisory Board, it is well worth a read. We are also grateful to the Imperial War Museum and Simon Jones, author of *Underground Warfare 1914-1918* for their assistance

### Cover

The Western Front during WW1. Underground warfare played a prominent role in the conflict.



### This month...

#### 20 YEARS AGO

Dispelling doubts over the likelihood of the Western Corridor Railway (WCR) being built, the Kowloon-Canton Railway Corporation (KCRC) says there is a 100 per cent chance its proposals will be accepted by the Hong Kong Government. *Tunnels and Tunnelling*, July 1996, p.7

#### 30 YEARS AGO

Italy, Austria and West Germany are considering the construction of a major new four track railway tunnel through the Alps linking Austria and Italy near the Brenner Pass. An earlier Italian proposal for a 56km-long tunnel through the base of the mountain range has been set aside in favour of this less ambitious proposal, to be built at a higher elevation. Work could start in 1988. *Tunnels and Tunnelling*, July 1986, p.9

#### 40 YEARS AGO

The longest hydropower tunnel in the world drilled from two headings holed through in May. The NZD 20M, 19.3km Moawhango Tunnel, part of the NZD 350M Tongairiro hydropower project in the centre of North Island was undertaken by Italian consortium Codelfa Cogefar. Tunnelling from one end started in August 1969 and the other started in January 1970. *Tunnels and Tunnelling*, July 1976, p.15

### Next issue

In the next issue of *Tunnels and Tunnelling* we have an article on monitoring the strength of concrete using thermal imaging cameras, as well as the second part of our special feature on tunnelling during times of armed conflict.

CHAPEAU SWITZERLAND

# PIONEERING PROJECT PAR EXCELLENCE

Congratulations to Switzerland and all pioneers on jointly completing and opening this groundbreaking project of the century in June 2016. A year ahead of plan, the iconic Gotthard Base Tunnel represents record progress set in stone.

HERRENKNECHT



Tunnelling Systems

[herrenknecht.com/Gotthard](http://herrenknecht.com/Gotthard)

In the Construction  
business...

...having the right tools for the  
job is critical to  
your success

Global Construction intelligence to drive  
growth and minimize risk

The Construction Intelligence Center is the most comprehensive source of data and analysis on the global construction industry. Our unique Construction Mega Project database tracks global projects over \$25 million and can be contextualized with our forecast of future project activity, rich market data and analysis as well as competitive intelligence and company activity.

We provide more data, insight, analysis and commentary than any other information provider in this industry. Our intelligence is designed to ensure our clients can better understand and exploit commercial pressures and market trends.

London: +44 (0)203 096 197  
Sydney: +61 2 8076 880  
New York: +1 646 395 546

sales@construction-ic.com  
www.construction-ic.com

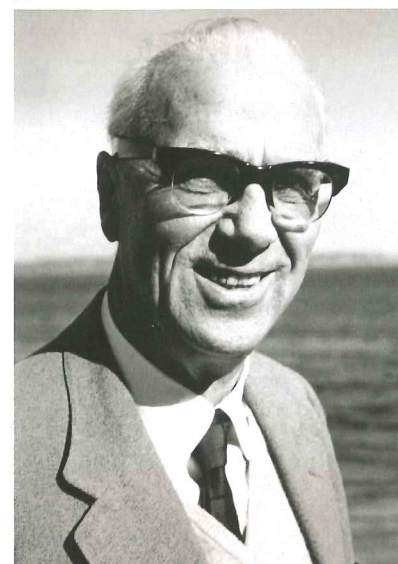
timetric

Head Office: 71-73 Carter Lane, London, EC4V 5EO • Tel: +44 (0) 203 096 2618 • Email: info@construction-ic.com • © Timetric 2016

36



14



35



Key people in this issue

- DÁNIEL BORBÉLY, MOTT MACDONALD
- TAMÁS MEGYERI, MOTT MACDONALD
- VERA SZÁNTÓ, MOTT MACDONALD
- LÁSZLÓ KOVÁCS, KÖMÉRŐ
- MYLES O'REILLY, RETIRED
- NAYAB SULTAN, SILICOSIS RESEARCH
- ROGER BRIDGE, BALFOUR BEATTY
- STEVE HARVEY, JOSEPH GALLAGHER
- PHIL STRIDE, THAMES TIDEWAY

www.tunnelsonline.info

News

- 7 News
- 16 The big picture

Reports

- 19 **Thames Tideway**  
Rhian Owen, journalist  
An early look at works required and what can be expected on the new super sewer project

Health and Safety

- 23 **SCL exclusion zones**  
Following a fatality on London's Crossrail project, the British tunnelling industry came together to produce a guide to manage spraying exclusion zones
- 29 **Silicosis**  
Nayab Sultan, Silicosis Research  
The Hawks Nest tunnel disaster is one of the most infamous underground health controversies
- 35 **Behavioural safety**  
Alex Conacher  
A UK subcontractor has launched a programme to improve its health and safety culture

Technical

- 38 **Crossing fault zones**  
Dániel Borbély et al  
Detailed analysis of radioactive waste repository design for the Bataapáti project in Hungary
- 45 **Wartime tunnelling**  
Myles O'Reilly, retired  
An insight into some of the techniques for and uses of tunnelling during wartime

Events and contacts

- 56 Dates and events
- 58 Contacts

The Construction Intelligence Center provides you in excess of\*:

- 80,000 Projects Globally
- 250,000 Contacts
- 75 Market Forecasts
- 10,000 Company Profiles
- \$40 Trillion in Projects

\*As our data is constantly updated the above metrics will continue to increase, keeping us ahead of a constantly evolving market.



20-22 September 2016

Peterborough Arena, East of England Showground, Peterborough, PE2 6XE



# NO-DIG LIVE 2016

2016

NO-DIG LIVE

Space selling fast!

The UK's only event dedicated to trenchless technology

- Daily demonstrations of equipment in live working environment
- Free entrance to the exhibition
- Free attendance at Breakfast Briefings
- New programme of introductory trenchless seminars
- UKSTT Training Seminars
- Free parking



Don't miss out - Contact Trevor Dorrell or Gary King today to check availability and secure your stand.  
Email: tdorrell@westrade.co.uk or gking@westrade.co.uk Tel: 0845 094 8066.

## New for 2016

The UKSTT Awards and Gala Dinner in Association with Westrade  
Wednesday 21st September at The Marriott Hotel, Peterborough

Get your team together, rally support and join us by booking a table at our prestigious event! Be visually dazzled by a troop of IT Girls, lavish in a Champagne reception, rejoice in your hard work and efforts throughout the year and applaud your fellow colleagues, as we take up the challenge to acclaim this event to be our best yet!

Supported by UKSTT Patrons



Organised by



Supported by



Media Partners



Gala Awards Dinner Platinum Sponsors



www.nodiglive.co.uk

## MASSIVE SINKHOLE DESTROYS ROAD IN OTTAWA

**CANADA** — A sinkhole appeared at about 10:30 a.m on 8 June near the corner on Rideau Street in Ottawa at a light rail construction site, according to the CBC. Large volumes of water have filled the collapsed road due to a broken water main.

Mayor Jim Watson said "it's premature at this point to make the connection to LRT, although that could very well be a possibility" during a press conference Wednesday afternoon.

He noted the tunnel work is "substantially below" where the water main break happened, and the tunnel hasn't been affected.

Crews were working in the tunnel at the time of the collapse and all safely evacuated.

The City of Ottawa confirmed there are no injuries and said the "infrastructure failure" will affect water service in the area and has closed nearby roads. The site is being secured and Emergency Services are on-site.

The mayor said work on the tunnel for the Confederation Line will be suspended while contractor Rideau Transit Group (RTG) stabilizes the situation and investigates.

## York Potash announces preferred contractors

**GREAT BRITAIN** — Sirius Minerals has revealed that the Hochtief Murphy joint venture is favoured to construct the mineral transport system at its North Yorkshire polyhalite project. This is the highlight of the York Potash job for the tunnelling industry and consists of a 23-mile (37km), 4.1m-diameter tunnel to transport ore from the mine site to the nearby port.

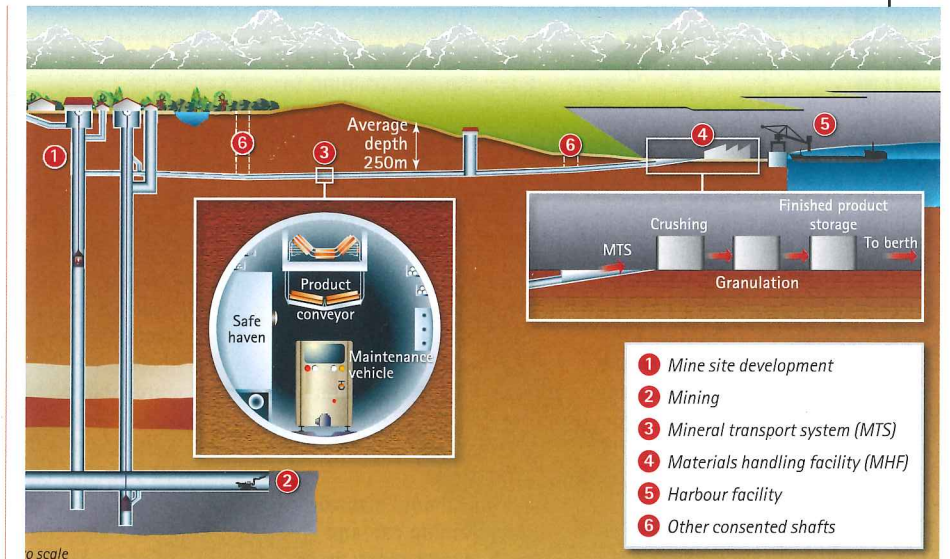
There will also be three intermediate shafts to support construction, then during operation they will be used for ventilation and maintenance access.

Five hard rock machines will excavate the Redcar Mudstone. Planning consent has been given for a 6m-diameter tunnel, but the design is still being finalised and the range being explored is 4-6m diameter. The tunnel will be lined with segmental rings with sprayed concrete for caverns.

As Tunnels and Tunnelling went to press, it was announced that the capital funding requirement for the project had been reduced.

A Sirius Minerals spokesman said: "By adopting the preferred contractor designs and estimates, changing the Project implementation approach and refining other components of the DFS estimate, a number of material reductions have been confirmed.

"As a result of this work the capital funding requirement for the Project has been reduced to USD 2.91bn (an 18 per cent reduction)."



Mineral transport system at the York Potash project



Location of the mine in the North of England

## RIYADH GREEN LINE TUNNELLING COMPLETE

**SAUDI ARABIA** — The completion of tunnelling of the Riyadh Metro Green Line was marked by a ceremony last month. The Green Line runs through tunnels dug along the route of King Abdulaziz Road, one of the city's main thoroughfares. It is 13km long and has 11 underground stations and two stations connecting with the Red and Blue lines.

The tunnels were excavated by two 9.77m TBMs. FAST received a USD 7.9bn contract to construct and design lines Four, Five and Six of the metro.

The Green Line is the fifth for the Saudi capital and is one of three being constructed by the FCC-led FAST consortium also consisting of Samsung C&T, Alstom, Strukton, Freyssinet, Atkins, Tyspa, and Setec. The others are the Yellow and Purple lines, which run along 22km of tunnel, 33km of viaduct and 9km of overground track.



FCC CEO Carlos Jarque with FAST consortium representatives

### New ITA President hails importance of education

**INTERNATIONAL** — Tarcisio Celestino issued a statement on the work of the ITA Committee for Education and Training (ITACET) last month. It follows:

"The Executive Council of ITA elected in April in San Francisco is working on the new version of the Strategic Plan of the Association for the coming three years. The work has not been completed yet, but the general guidelines which have been discussed so far indicate that knowledge sharing will go on as one of the goals to be reached.

"The previous Strategic Plan included "Encourage of further knowledge sharing through Education and Training" as one of the goals. Much has already been achieved by means of actions promoted by the ITACET Foundation and the ITACET Committee. However, as time goes by, we find out that more and more is needed with respect to training. In fact it can be considered as an endless objective.

"The establishment of the ITACET Committee activity

groups on Education and Training for Member Nations, Education and Training for Professionals and University Networks seems not to have been fully explored yet, except for the first one, the activities of which have already been underway since the establishment of the Committee. Actions for development of the two other activity groups were discussed in a meeting last April in San Francisco and the new possibilities are promising.

"We should also consider that training can and shall involve many areas, some of which have not been covered in most of the courses offered so far. A good example of what has just happened in this direction is the topic of use of underground space. Fortunately that was the topic of one of the courses offered in San Francisco last April.

"I am sure that the success of ITA depends largely on close and fruitful cooperation with both the ITACET Foundation and the ITACET Committee. I am here encouraging all parties to work hand in hand for the same objective."

### Britain not skilled enough to leave EU says recruiter

**GREAT BRITAIN** — Britain does not have the numbers of skilled engineers to leave the EU according to recruitment specialist Jam Recruitment. James Turnpenny, team manager for engineering at the company has added engineering employment to the growing list of sectors that may be negatively impacted by the 'Brexit' vote.

"It's already been reported that the UK will need over a million new engineers and technicians by 2020 in order to tackle the skills crisis .

"Put simply, the UK doesn't currently have the required levels of trained workers within the engineering industry to leave the EU. Across many industries we're in a similar position as we find ourselves in with engineering. Within the sector, there is currently a war for talent, as we're not in a position where we have the trained homegrown workforce that would allow us to continue operating at a level the industry requires. The much publicised current skills shortage means we're increasingly looking to other

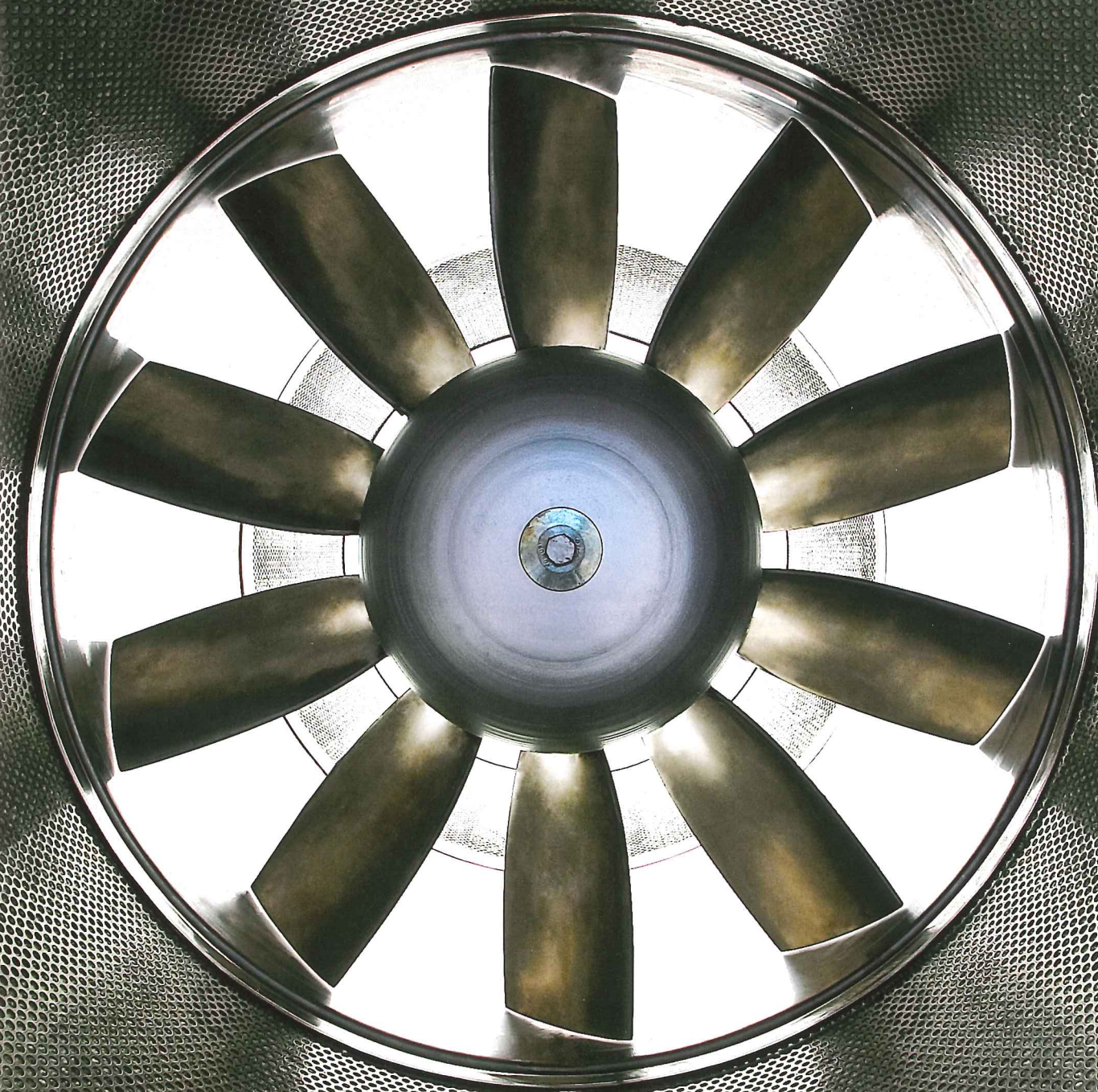
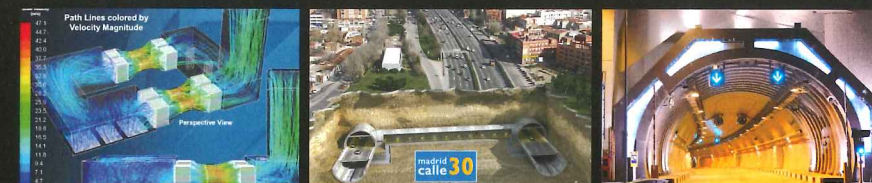
nations to source workers who possess the required skillset to fill roles.

"Presently, a high proportion of students enrolled in engineering courses are overseas students meaning that once they're qualified they may decide, or be forced, to return home – a victory for the 'Yes' campaign would certainly have an impact on the number of skilled workers in the UK."

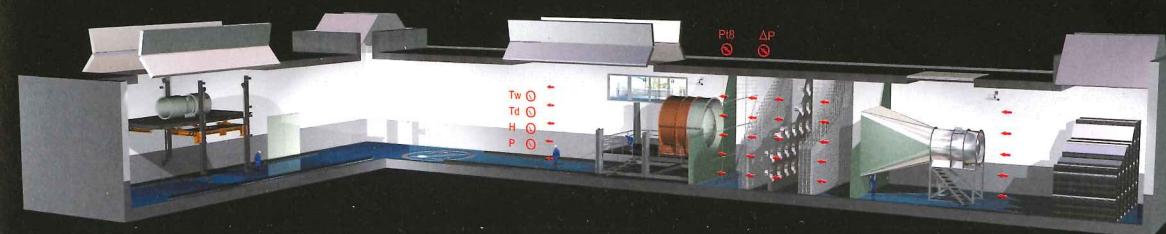
### UK firms join London Pride Parade for second time

**GREAT BRITAIN** — Several leading UK construction firms took part in the London Pride event in late June. Arup, Arcadis, Balfour Beatty, Carillion, Laing O'Rourke, Lend Lease, Mott MacDonald, Nathaniel Lichfield & Partners, Skanska, and WSP Parsons Brinckerhoff took part Under the slogan #BuildingEquality.

"Last year was the first time an engineering or construction firm marched at Pride in London. There has been a visible increase in LGBT awareness and inclusion in the engineering and construction sector," announced Arup.



The legend in ventilation systems



"The biggest certified test tunnel in the world"

Over 50 years of experience, a high degree of technological competence and highly qualified staff endorse our work which is among the most valued and acknowledged in our sector.

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

**Robbins appoints Lechner**

**USA** — Manufacturer Robbins has appointed Joe Lechner as its new Small Boring Unit (SBU) manager.

A spokesman for the company said: "With over 18 years of industry experience, the role is a natural career progression for Lechner. It brings him back to his early roots of working with SBUs, while more recently he worked with TBMs. Lechner can continue his success with the company in this new capacity with the trenchless division.

"Lechner began working with SBUs in 1998, starting in field service. When he wasn't out in the field, he was building SBUs and cutters.

"He started up and commissioned SBU-As in the field, and transitioned over to working with TBMs worldwide in the mid 2000's. With his diverse worldwide field experience, Lechner's knowledge will continue to benefit Robbins and its customers."



Joe Lechner

**PERI enters Tanzania**

**TANZANIA** — Formwork and scaffolding supplier Peri has opened a subsidiary in Tanzania.

The east African country "offers excellent economic conditions for the introduction of formwork and scaffolding products and services," according to Peri. Additionally, it is considered a gateway to many landlocked African countries.

**Parsons awarded Deep Wastewater Project in Dubai**

**UAE** — Parsons announced that it was awarded

a contract by Dubai Municipality for two deep wastewater tunnels and associated link sewers.

The AED 6.4bn (USD 1.74bn) contract covers feasibility studies, preliminary design, tender preparation and general support. The total combined length of the tunnels will be more than 70km, with approximately 140km of link sewers and a number of 'key' pumping stations.

A spokesperson for Parsons said: "When complete, the project will eliminate more than 100 pump stations throughout the city that currently transfer wastewater to treatment plants in Al Warsan and Jabal Ali.

"The primary objectives for the sewer project are to reduce the overall cost of treating wastewater in the Emirate, reduce carbon emissions through the use of gravity sewer systems and decreased power consumption, and prepare for Dubai's expected population growth."

**Latest Delhi breakthrough**

**INDIA** — The Delhi Metro Rail Corporation (DMRC) achieved another tunnel breakthrough on Phase III of its project.

The site in South-West Delhi saw completion of tunnelling on the under construction Dwarka-Najafgarh corridor (Line-9).

The TBM emerged near the Tura Mandi site after making a 0.67km-long tunnel from the site near Sai Baba Mandir.

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



editor@tunnelsonline.info

**RIDHAM PRECAST FACILITY FIRES UP**

**GREAT BRITAIN** — The precast facility at Ridham Dock in Kent has begun work. The factory will supply the Ferrovial Agroman-Laing O'Rourke JV with concrete segments to line the Northern

Line extension project. The Morgan Sindall-owned site received a GBP 8M (USD 11.1M) order for the project.

The Northern Line Extension requires 3,280 no. 5.2m-diameter rings for 2.4km

of twin tunnel. Ridham can produce 70 rings per week according to Morgan Sindall, with 45 people working over two shifts.

David Hicks, Morgan Sindall's senior operations manager at the Ridham facility, said: "It's great to be remobilising the facility and recreating opportunities for the local community. We're currently re-commissioning the factory, getting it ready for production ahead of the start-up date in July. We're pleased that our capabilities here will help with the completion of key infrastructure upgrades in London".

The last major order was for the Lee Tunnel project, which runs for 7.8km and required 7.8m-diameter rings.

The site was set up 15 years ago to support Morgan Sindall's tunnelling business unit and supply segments to the Heathrow Terminal Five project. It was sited at Ridham, not only to be close to the tunnelling work on that project, but also due to its proximity to London for future work such as the Lee Tunnel and Northern Line.



The storage yard outside the main factory

**normet**  
FOR TOUGH JOBS

**FOR TOUGH JOBS UNDERGROUND**

EQUIPMENT | CONSTRUCTION CHEMICALS | ROCK REINFORCEMENT | LIFE TIME CARE

www.normet.com

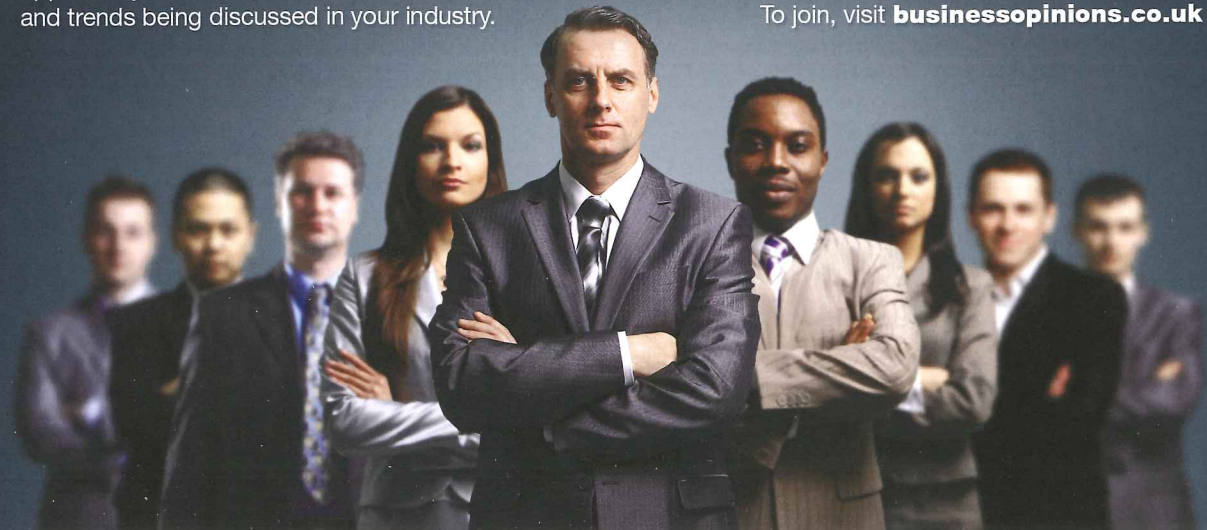
**BUSINESS OPINIONS**

The Business Insight Community

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

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

To join, visit [businessopinions.co.uk](http://businessopinions.co.uk)



## ZUBLIN TO BUILD CHILEAN UNDERGROUND MINE

**CHILE** — Strabag announced on 13 June its subsidiary Züblin International Chile, has been awarded a EUR 400M (USD 448M) contract by Codelco, the world's largest copper producer to transform the Chuquicamata open pit copper mine into an underground operation.

Chuquicamata, located in northern Chile, approximately 1,650km north of Santiago, is the world's largest open pit mine and will require a total of 63km of tunnel excavation, some 7km of shafts and the transportation of 3.6 million tons of materials to convert to an underground operation.

The latest construction works on the venerable mine, which first began operation in 1910, should be finished in 2021.

"With this project, our subsidiary Züblin will expand its current presence with Codelco," said Thomas Birtel, CEO of

Strabag. "Besides the Chuquicamata Mine we are also working on the El Teniente Mine and in the Andina Mine. Our many years of experience in the mining sector in Chile are very appreciated by our client." Züblin International Chile was founded in the year 2000 and maintains its headquarters in Santiago de Chile.

The company is a subsidiary of Ed. Züblin and forms a part of Austria's Strabag. Züblin International Chile has about 2,700 employees.

State-owned Codelco produces approximately 11 per cent of the total world copper supply but recent years have not been kind to the company. In March the company announced losses of USD 1.4bn for 2015 and president Nelson Pizarro said the year was the worst ever for the mining giant. Copper prices had dropped by up to 20 per cent.

### John Holland opens new office

**SINGAPORE** — John Holland has opened a new South East Asia office in Singapore. The company's regional general manager for South East Asia, John Anderson, said that the region had a promising pipeline of work and excellent potential for growth.

Anderson added: "The move also coincides with the award of the contract to construct the new Siglap Station on the Thomson-East Coast Line in Singapore (Contract T309), as part of a joint venture with Zhen Hua, another CCCC company.

"The new contract win provides a fantastic opportunity to continue the positive working relationship we have with the Land Transport Authority through our work on T208, which involves construction of Springleaf Station and tunnels on the Thomson Line, and C935 on Downtown Line 3."

### People moves

Len Murray, president and CEO of Vancouver-based Klohn Crippen Berger (KCB) announced an array of principal and associate appointments on 8 June.

#### SIMON DOUGLAS

Since joining KCB's Power and Transportation Group in 2005, Simon, a Senior Civil Engineer, has managed large multi-disciplinary teams and demonstrated strong technical, engineering, client and leadership skills in his role as KCB's Project Manager for the BC Hydro Site C project.

#### RICK FRIEDEL

Since joining KCB in 2003, Rick has completed long-term assignments in our Mining Environmental Group (MEG) offices in Canada, South America and Australia. Rick returned to BC in 2011 to start up a group in Vancouver to support the company's oil sands work and shortly thereafter was promoted to Manager of the MEG Engineering team.

#### TIM KEEGAN

Tim is a Senior Geotechnical /Geological Engineer and Manager of our Edmonton office. Tim has over 30 years domestic and international design, construction and operations experience for roads, railway, water resource and tailing dams, environmental, pipeline and mining projects. He leads our design projects, regulatory approvals, and construction management for railway infrastructure across North America, and for geohazard/ground-hazard risk management programs.

#### BRIAN BORTON

Brian has worked on a wide variety of projects throughout North America and, since joining KCB in 2003, he has gained extensive structural design and analysis experience as well as project and design management experience on civil infrastructure projects including bridge, hydro and heavy industrial projects.

#### KATE PATTERSON

Since joining KCB in 2007, Kate has gained extensive experience as a civil engineer, technically specialising in climate and hydrology assessments, hydrotechnical design, erosion estimation and protection, tailings staging, sedimentation pond design and cover design. She has excelled in project management and coordination for a number of projects from conceptual studies to existing mines.

#### ROBERT CROSS

Rob has extensive experience in the transportation, hydroelectric and mining sectors. He joined KCB in 2009 after receiving his M.Eng. in Geological Engineering and has since worked on projects in North America, South America, Africa, and Asia. Rob's entrepreneurial spirit led him to Toronto in 2012 to take on the role of office manager at our new location there.

#### CHRIS GRÄPEL

Chris is a Civil/Geotechnical Engineer with over 20 years of experience in dams, water resources, mining and transportation (highways and railways) engineering and construction. He joined KCB in 2012 and has worked in both our Edmonton, Alberta and Lima, Peru offices. Chris is currently responsible for the Edmonton Civil Projects group, and the expansion of our services with the Alberta government, City of Edmonton, mining and utility clients.

#### ROBERT CHEETHAM

Rob is a Senior Civil Engineer with over 20 years of international experience in the civil, water resources, river engineering and floodplain mapping, hydrological and hydraulic analysis and surface water management for private and municipal clients. Rob is responsible for managing and coordinating projects for the City of Calgary, TransAlta and SaskPower, developing conceptual and feasibility designs, preparing design documentation and reports, and providing support during construction.

The most anticipated Urban Underground Space & Tunnelling conference in 2016!

## URBAN UNDERGROUND SPACE & TUNNELLING ASIA SUMMIT 2016

6 - 9 September 2016, Singapore

Book and pay by **13<sup>th</sup> May 2016** and save up to **SGD 1,900!**

**Main Summit Dates:** 7 & 8 September 2016

**Workshops Date:** 6 & 9 September 2016

Asia's Leading Urban Underground Space & Tunnelling Summit will return this September in Singapore to discuss leading practices, innovative techniques and sustainable solutions for Design, Engineering & Construction of Underground Space and Tunnelling Projects!

**Urban Underground Space & Tunnelling Asia Summit 2016** will provide excellent insight into the complexity and challenges of tunnelling in urban areas, mitigating construction risk, tunnelling through difficult ground conditions and managing groundwater inflows as well as issues relevant to the design and construction of underground works.

### KEY SUMMITS HIGHLIGHTS

- 1 Case Studies** Hear from Qatar Rail, Cityringen Metro and MTR Corporation Limited amongst other leading project owners/government authorities and engineers share their latest experiences in Underground Space Construction & Tunnelling Construction
- 2 Full Scale Coverage & Networking** A unique event truly dedicated to all professionals in Underground Space & Tunnelling industry. Experience a diverse networking opportunity with over 100 like-minded industry professionals from government authorities, project owners, engineering contractors and design engineers in Asia
- 3 Best Practices** Qatar's Metro, Copenhagen's Metro, Barcelona's Metropolitan Railway, Hong Kong MTR and Canada's Vancouver Line amongst other project owners/government authorities will share best practices in planning, designing, engineering and construction of urban underground space infrastructure and tunnelling projects
- 4 Detailed Presentations** Gain insights from industry experts on how you can overcome key tunnelling & underground construction challenges, effectively phase/plan your projects, manage your project costs, budgets & schedules for complex underground space and tunnelling projects
- 5 In-depth Workshops** Attend 4 Expert-Led Workshops to grasp the nuts and bolts of underground space construction and tunnelling

**PLUS!!!**

4 separately bookable workshops on **6 & 9 September 2016**

- WORKSHOP A** Innovations and Practical Approaches in Underground Construction & Tunnelling in Urban Environment
- WORKSHOP B** Identifying Best Practices in Rock Cavern Design and Rock Mechanics
- WORKSHOP C** Maximising Efficiency in Design and Construction of Tunnels and Cavities
- WORKSHOP D** Developing Effective Solutions for Underground Space Construction in Difficult Ground Conditions

*Urban Underground Space & Tunnelling Asia Summit 2016 brings together industry leaders across Asia Pacific under one roof. Definitely a must-attend event!*

- Dr. Paul James, Tunnel Director, Eptisa



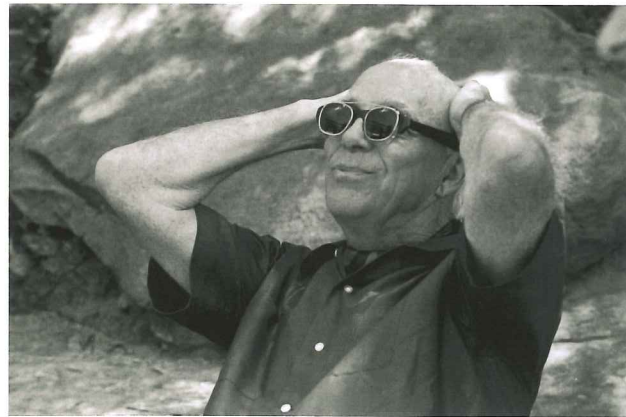
## ARUP RETROSPECTIVE OPENS IN LONDON

**GREAT BRITAIN** — The Victoria & Albert Museum (V&A), London, is staging the first major exhibition about Ove Arup, opening Saturday, June 18.

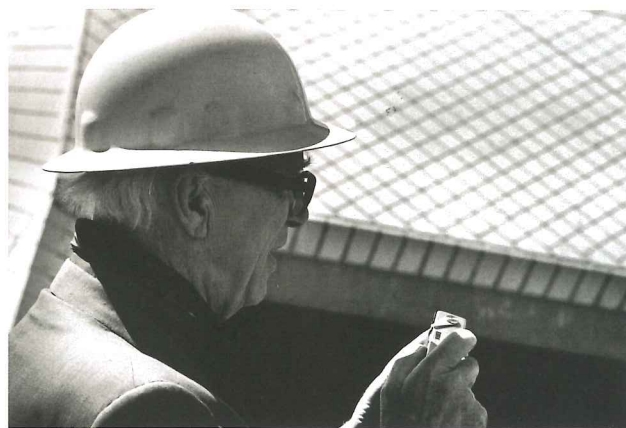
“Engineering the World: Ove Arup and the Philosophy of Total Design” will showcase the life, work and legacy of the firm’s Anglo-Danish founder.

The exhibition, curated by Zofia Trafas White and Maria Nicanor from the V&A’s Design, Architecture and Digital department, will cover more than 100 years of engineering design. On display will be more than 150 objects including previously unseen prototypes, models, archival materials, drawings, film and photographs presenting how Arup redefined civil and structural engineering and pioneered a multidisciplinary approach to design, which the firm still adopts today.

“Ove Arup was the greatest engineer of the 20th century,” White said. “Unconventional and playful in his approach, his collaborative working style revolutionised building design during his lifetime and influenced how buildings are made today. Ove Arup’s career began at the height of the Modern Movement in the 20th century and went on to last over five decades. The exhibition will paint a picture of the man whose ideas led to the creation of one of the most innovative and influential engineering consultancies



All: Ove Arup



working today and will present Arup’s key contributions to almost one hundred years of engineering developments in built environment design. Engineering the World will shed new light on the behind the scenes engineering stories that made possible some of the world’s most iconic buildings.”

The show highlights Ove Arup’s approach to ‘Total Architecture’, the adoption

and development of innovative technologies, and how cutting-edge engineering solutions have changed the built environment. Stories behind the development of famous historic buildings such as the Sydney Opera House and the Centre Pompidou in Paris will be revealed alongside current projects such as Crossrail and HS2. In addition, the recently developed SoundLab and



SolarLeaf, an experimental bio-reactive façade system that uses microalgae to generate renewable energy, will allow visitors to immerse themselves in the creative and collaborative work of engineers, architects and designers who, together, design our buildings, cities and urban systems.

“Ove Arup founded our firm with a highly original vision, combining philosophy and engineering to create a holistic approach to design that he called ‘total architecture,’” said Tristram Carfrae, Arup fellow and deputy chairman of Arup Group. “Given the significant challenges the world faces, this pioneering approach to engineering design has never been more relevant than today. For his life and our on-going work to be recognised and celebrated by such a world renowned institution as the V&A is very gratifying. It demonstrates how Ove was a pioneer of his time and how the firm continues to follow his pursuit of creativity and innovation based on world class expertise. The V&A tells this story beautifully and we feel sure this exhibition will be an inspiration to the next generation of engineers, designers and all those interested in the built environment.”

Engineering the World: Ove Arup and the Philosophy of Total Design is the headline exhibition for the V&A Engineering Season. The exhibition will run from 18 June – 6 November 2016.

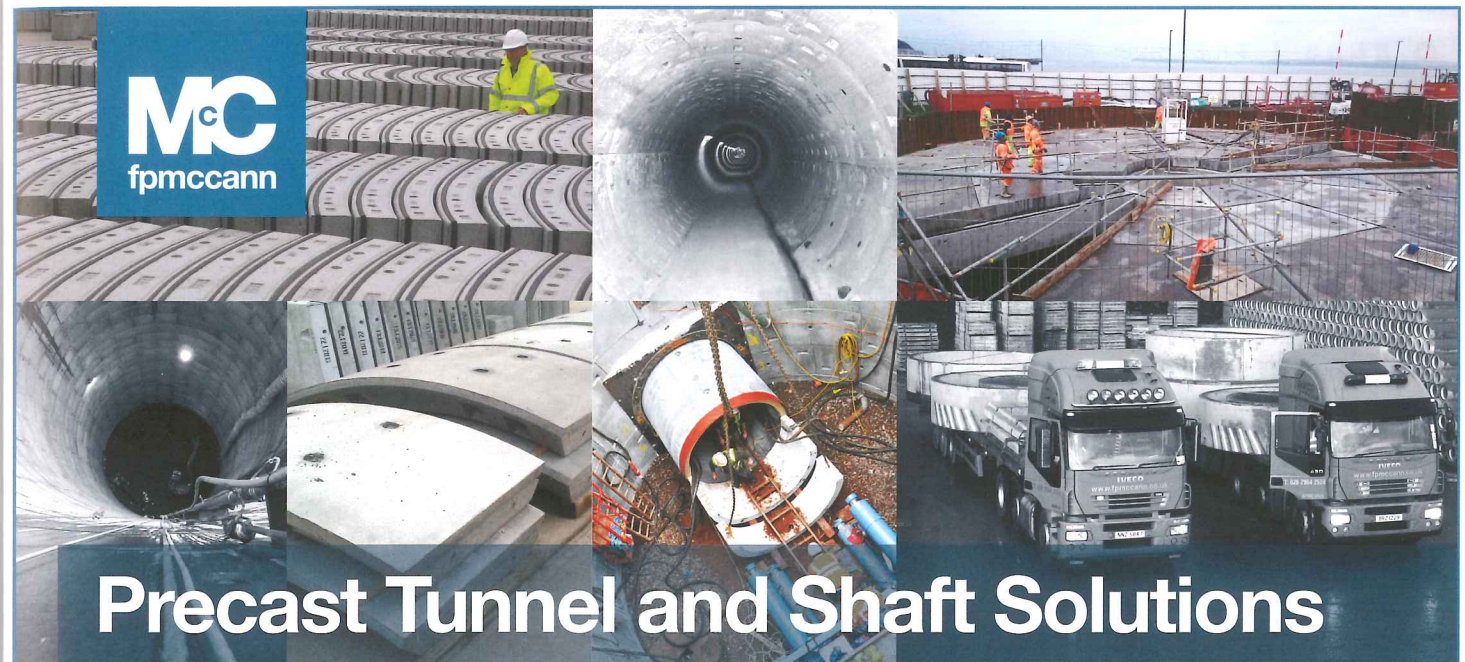
### Letter

Dear Sir,

I fully support the views of Eddie Woods, chairman of the T&T Editorial Advisory Board writing in last month’s issue. I think it is useful to let readers see how tunnelling practice varies around the world. It is timely also to remind UK readers that not all conventional tunnels are excavated by machines with a robotically applied lining of sprayed concrete in spans of over 10 m. In the UK we have become used to Crossrail station enlargements and forget that not all tunnels are like that. We forget also that it is only two decades since station enlargements on Jubilee Line Extension were being excavated by hand by miners, many of whom were working in compressed air, with cast iron lining also being erected largely by hand with air winches for assistance.

The unacceptably high levels of DCI on JLE Contract 105 were one of the triggers for the introduction of oxygen decompression in the UK.

Donald Lamont, Hyperbaric and Tunnel Safety



## Precast Tunnel and Shaft Solutions

[fpmccann.co.uk/tunnels-shafts](http://fpmccann.co.uk/tunnels-shafts)

FP McCann offers a complete range of Tunnel and Shaft solutions including our Smoothbore Shafts from 2.44m - 25m diameter, bespoke cover slabs made to specification, full range of Jacking Pipes from DN450 - DN2400 and Caisson Rings from DN2100 - DN4000.

Contact a member of our Tunnels & Shafts team on 01455 290780 or email [sales@fpmccann.co.uk](mailto:sales@fpmccann.co.uk)

## SOFRASAR TUNNEL PRODUCTS

Tunnel Infrastructure teams trust Optimas for their segment accessories solutions.

- Products, engineering and design
- 350+ completed projects worldwide
- At your side for over 20 years

**OPTIMAS**

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

**MASTER BUILDERS SOLUTIONS**

SAFE, EFFICIENT, RELIABLE, DURABLE, PERFORMING  
SUSTAINABLE, ECONOMICAL, GROUND SUPPORTING  
OPTIMIZING, FLEXIBLE, STRONG, WORKABLE DESIGN  
GROUND CONSOLIDATING, WATERPROOFING  
REBOUND, WATER STOPPING, GROUND SUPPORTING  
SAFE, PERFORMING, EFFICIENT, DURABLE, RELIABLE  
ECONOMICAL, FLEXIBLE, STRONG, WORKABLE DESIGN

» I NEED SAFE AND EFFICIENT TUNNELING.

Safety and performance are BASF’s first priorities in tunneling. This calls for specialized engineering support, application know-how and state of the art chemistry. BASF can fulfill your needs with its Master Builders Solutions. Whether you are looking for ground support & consolidation, an efficient TBM or waterproofing, our leading global expertise in sprayed concrete, injection, mechanized tunneling solutions and membrane technology will help you build your tunnel safely and economically.

For more information please visit [www.master-builders-solutions.com](http://www.master-builders-solutions.com)

**BASF**  
We create chemistry



**Left:** Break through on the Túnel Emisor Poniente (TEP II) project in Mexico

# UNDERGROUND UTILITIES

**Underground Utilities is the only magazine that covers the entire underground construction market from trenchless technologies to innovative pipe repair methods and modern trenching equipment. As sister magazine to Tunnels and Tunnelling International, Underground Utilities is circulated to over 6500 readers in over 100 countries.**

**UNDERGROUND UTILITIES**

Subscribe:  
<https://secure.buythatmag.com>

Advertising Contact:  
[tom.willard@uu-magazine.com](mailto:tom.willard@uu-magazine.com)

Editorial Contact:  
[bernadette.ballantyne@uu-magazine.com](mailto:bernadette.ballantyne@uu-magazine.com)

Read a recent issue:  
<http://viewer.zmags.com/publication/b865d7aa>

# TROUBLED WATERS

The Tideway Tunnel, a major new sewer that will help tackle the problem of overflows from the capital's Victorian sewers, has caused controversy since its initial proposal. **Rhian Owen** looks at the lengthy site selection process that was undertaken and the scope of work that lies ahead to bring this project to completion

**Rhian Owen**

Rhian began working with *Tunnels and Tunnelling* in 2011



**B**EFORE SIR JOSEPH BAZALGETTE'S sewer network, during the hot, dry summer of 1858, the smell from the Thames was so appalling that the curtains in the Houses of Parliament were soaked in chloride of lime in a vain attempt to protect the sensitivities of politicians. As a direct result, a bill was rushed through Parliament allowing civil engineer Bazalgette to construct a massive new sewer scheme for London.

150 years later, Bazalgette's interceptor sewers are still the backbone of London's sewer network today. His design centred around using the city's natural drainage system of 'lost rivers', such as the Fleet and the Tyburn, which had already been built over before Victorian times, to flow into his new interceptor sewers and transfer to balancing tanks in east London.

Bazalgette was a great visionary for London. "The interceptor sewers were the largest civil engineering project in the UK in the 19th Century," says Phil Stride, director of external affairs at Tideway. "When he designed them in the late 1850s there were two million people in London, he had the vision and foresight to deliver to four million people, and now there are eight million people. So while they are in excellent condition, it doesn't take a lot to imagine that they struggle in terms of capacity."

When Bazalgette's sewer network was being designed, there was no reason to believe London's population would rise exponentially to its current levels, or how much water and solid waste would be dispersed. In times of severe storms, the system was designed to overflow through discharge points on the banks of the river into the River Thames, rather than flooding streets and homes.

When designed, this would have happened once or twice a year. It now happens every week, on average. "In a typical year 39Mt of sewage is discharged into the tidal River Thames and figures for 2014 show 62Mt of sewage was discharged into the Thames, which is a big problem," says Stride.

The proposed solution is the super sewer – also known

as the Thames Tideway Tunnel. "The Thames Tideway tunnel is the only solution that can be delivered to meet the standards set by the Environment Agency and within the timescale set by Government," he explains.

## WORK BEGINS

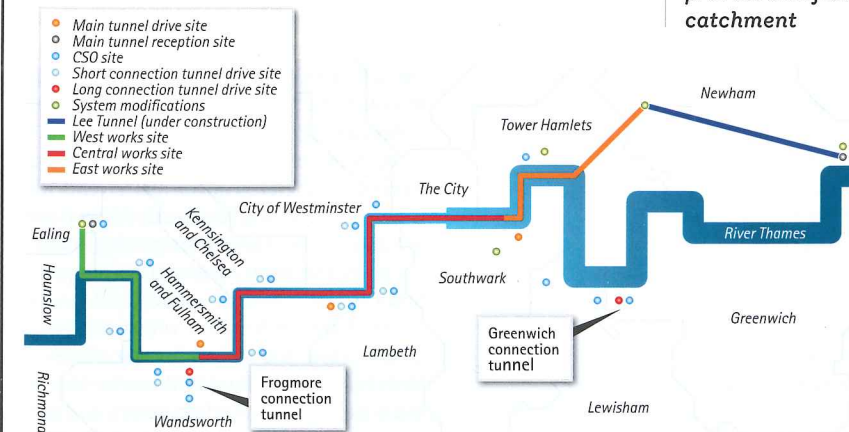
Construction work for the Central 25km interception, storage and transfer tunnel running up to 65m below the river, starts this year. The Thames Tideway Tunnel will be built from three main construction drive sites, under three separate contracts, in Fulham, Battersea and Southwark and will require the use of 24 construction sites, 11 of which are located along the river bank.

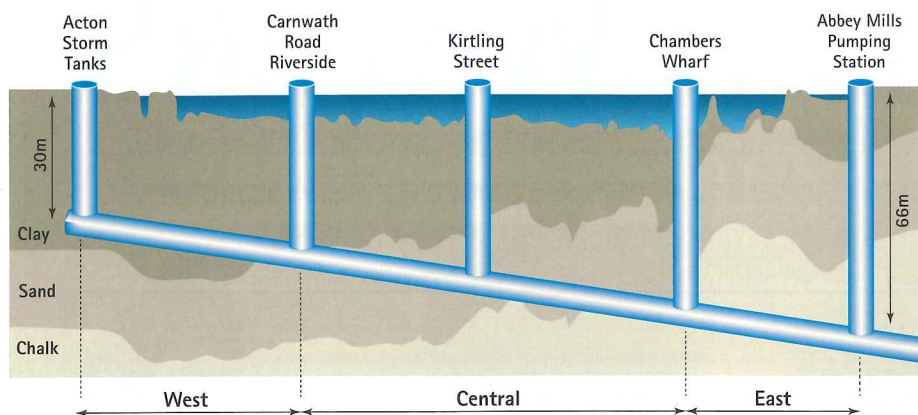
A joint venture between Laing O'Rourke and Ferrovial Agroman has landed the largest central section drive worth GBP 600M to 900M. The eastern section of the tunnel has been bagged by a Costain, Vinci and Bachy JV and is expected to cost GBP 500M to 800M (USD 734M to 1.174bn). While the consortium consisting of Balfour Beatty, BAM Nuttall and Morgan Sindall has picked up the shorter western tunnel drive, which is expected to be worth around GBP 300M to 500M.

"The tunnel will run from Acton in the west of London down to Hammersmith, and from Hammersmith it follows from west to east the route of the River Thames, all the way through west London and central London to a site called King Edward Memorial Park in the London borough of Tower Hamlets. From there it goes up to Abbey Mills Pumping Station. There are also two connection tunnels – one from Greenwich Pumping Station to Southwark and the smaller Frogmore connection tunnel," says Stride.

A joint venture between Laing O'Rourke and Ferrovial Agroman has

*Below: The Thames Tideway project runs along the route of the river to provide overflow catchment*





Above: Tideway contract sections divided by shafts

landed the largest Central section drive. The Eastern section of the tunnel has been awarded to a Costain, Vinci and Bachy joint venture, while Balfour Beatty, BAM Nuttall and Morgan Sindall has picked up the shorter western tunnel drive.

### SITE SELECTION

The Thames Tideway Tunnel has not been without controversy. Since its initial proposal, questions were raised on the cost – the project is expected to cost GBP 4.2bn (USD 6.16bn) – the location of construction sites and duration and associated disruption of the works.

“As we are tunnelling through a built up area, there was always going to be some controversy or debate on the sites we ultimately selected,” notes Stride.

“We thought with that being the case it was really important that we agreed on the method we would use, so we could just debate how the method was going to be used. Otherwise we would have people tell us that they didn’t agree with the site we had chosen and they don’t agree with the method we’ve chosen to select the site. So that’s what we did and we originally considered more than 1,100 sites.”

These potential sites were then further evaluated against more detailed planning, engineering, environmental, property and community considerations resulting in a shortlist of sites.

“It is no good from a design point of view if we think it would be really good to have a site in a certain area but all that is there is residential buildings, or even areas of land where people are currently developing,” explains Stride. “Since one of the criteria of the site selection methodology was to not knock down residential property, so it’s a very iterative process of looking at the design, looking at what was available, seeing what was available and feeding it back into the design. So that led to our original scheme, which we then put out for consultation in September 2010.”

### CONSULTATION INUNDATION

Stride said that through the process more than 9,000 pieces of feedback were received. In response to the comments received, changes and improvements to some of the sites were made. “In all that feedback we received there were two key messages that could be summarised; where you can build on brownfield instead of greenfield, and where you can use the river for transporting materials rather than the road.

“So we changed our plans significantly. Some of the main drive sites changed for instance. One in the West, was originally in a place called Barn Elms, which is in a playing field, is a good example of where we went from a greenfield site to a brownfield site.”

The second consultation took place during November

2011, and the planning application was submitted in February 2013. This was the largest planning application ever submitted in the UK.

“The key challenge in any built up area is that we will do everything we can to be a considerate neighbour,” explains Stride. “We committed to do everything we could to limit noise, dust and light from the construction sites, and also initially addressing the development consent order process we did everything we could to move materials by river rather than road – for example, we committed to moving a minimum of 90 per cent of the material from the main drive excavations by river.”

Michael Francis, tunnels practice leader, Mott MacDonald, adds that most of the sites have unique challenges. “At Greenwich Pumping Station the shaft is constructed close to a Grade 2 listed building and the DLR viaduct; at Earl Pumping Station the site is contaminated and there is limited space due to the configuration of existing structures; King Edward Memorial Park and Deptford Church Street Sites are in the context of public open space park areas.

“Breaking into the existing Victorian sewers is challenging in all cases. We are using comprehensive BIM models to ensure we have a multidisciplinary design which is totally integrated. We are developing a sustainable design that builds on experience gained on the Lee Tunnel Project and challenges the conventional approach with innovation wherever possible.”

The project also includes makeovers of local areas; for example, at Barn Elms, Tideway will be providing modern changing rooms and a cafe for people using the sport pitches, there will be more viewing platforms along the River Thames, and at Deptford Park Street – where the tunnel will connect to the sewer under the park – the park will be regenerated through landscaping with the local community.

After more than five years of consultation, planning and the awarding of contracts, the first visible signs of construction activity were apparent late in 2015 in central London. “Having worked on the project for many years it is quite an exciting landmark that we are actually out on these sites getting them ready for the main construction,” says Stride.

At Chambers Wharf – which will be used to drive the main tunnel to Abbey Mills Pumping Station and receive the main tunnel from Kirtling Street, to the west – the site is being prepared for the

main construction works. The works include the demolition of structures including a substation and removal of stockpile. “Thames Water are removing massive amount of rubble that was left on the site when it was purchased by the firm in 2011. So there is a big operation on clearing the site by river.”

At Blackfriars Bridge work has begun, this time by Tideway, to prepare the site for the main construction to start. Work includes construction of the new Millennium Pier, to replace the existing Blackfriars pier, which is being moved to make way for work under and around the road and rail bridges, a new public lift and staircase to access Blackfriars Road Bridge while the existing pier is taken out.

Adjacent to the pier was moored the ex-HMS President, the 98-year-old WW1 veteran Q ship, which has now been tugged down to the Medway for restoration.

### GEOLOGICAL INVESTIGATIONS

In order to begin the main works, Tideway undertook the biggest linear geotechnical investigation to take place in London. “We’ve done over 300 boreholes – either land based ones or ones in the river over the line of the tunnel,” says Stride. “It’s a very extensive geotechnical investigation.”

Now that most of the London Clay formation has been used up by tunnelling projects, new tunnels are being forced to go deeper and penetrate the Lambeth Group deposits more and more. Thames Tideway Tunnel goes through all of London’s geology including London Clay, Lambeth Group, Thanet Sands and Chalk.

“The geology in the west is London Clay; so the shaft at Carnwath Road Riverside is roughly at the point where the geology changes from clay at the tunnelling horizon to mixed sands and gravel,” explains Stride. “Then there’s mixed sands and gravel generally all the way through Central London both sides of Kirtling Street all the way through to Chambers Wharf.

“There we’ve got Thanet Sands and Lambeth beds. On the eastern section we have chalk, which is similar to where Thames Water worked on the Lee Tunnel, the link between Abbey Mills Pumping Station and Beckton and the tunnel the Thames Tideway Tunnel will connect into.”

In the west, Tideway is anticipating the use of an EPBM, while it is expected that a slurry machine will be used for the eastern sections, since a slurry machine

was used for excavating the Lee Tunnel.

Stride says: “One of the best understood tunnelling mediums is through London Clay, which is what we have in the west. In the centre, as we get deeper we have more water pressure to deal with – it will go up to seven or eight bar when you get to Abbey Mills Pumping Station.

In the central section, another challenge is that we have mixed sands and gravels. The TBM needs to be designed to deal with the water pressure and the mixed sands and gravels it will encounter.

“In the east, where the water pressure is greatest of the three sections because it’s deepest, we’ve got chalk. Although chalk is a good tunnelling medium, the key challenge there is the flints within it. So a slurry machine that is capable of dealing with flints – some of the flints we are anticipating are 1m across – and the TBM needs to cut these without getting damaged.”

In addition, Francis says that they expect to encounter contamination during shaft excavation in the historic industrial areas on some sites. “This will require special measures including ground treatment to minimise risk to construction personnel and the public. The shafts lined with diaphragm wall and internal linings are designed to minimise risks in construction.

The TBM is designed to reduce risks associated with a high proportion of flints and the possibility of a dip in the top level of the chalk. Linings of shafts and tunnels are designed as composite structures to provide structural capacity.”

### LINING AND PRODUCTION

The main tunnel will be lined with a primary steel fibre reinforced segmental lining. Inside the segmental lining it will have a secondary cast in-situ lining, and Tideway is currently looking at how that will be reinforced.

Both sprayed concrete lining and pipe jacking are being considered for the primary lining for the connection tunnels, and have a cast in-situ secondary lining.

The project timeline has shifted, and the completion date has been brought forward from 2024 to 2022, Stride notes. “Our CEO, Andy Mitchell, challenged the main works contracts to see how they could reduce the programme, while not in any way compromising health and safety.”

Stride adds: “When we’re in full production we are going to employ some 400 to 450 people at the main drive site. We’re getting on and setting up. What’s going to be starting towards the end of this year, beginning of 2017, is we’re going to be constructing the main drive site shafts. Towards the end of 2017 after that’s completed we’ll start the main tunnelling. We’ve just agreed our Strategic Target Schedule and we’re working towards completion in 2022.”

Stride says that Tideway is creating “more than just a tunnel”. Tideway is hoping the project will impact the city’s economy – 90 per cent of the expenditure will take place in the UK and the company has challenging targets around local employment and using small enterprises – plus improve the aquatic environment.

“Furthermore, our vision for the project is to reconnect London and Londoners with the River Thames,” says Stride. “Over the years, the Thames has been less clean than it is now, there are good examples of people building along the Thames where they’ve actually faced the building away from the Thames as opposed to towards the river.

“We are keen to create a legacy that everybody can be proud of; we want Londoners and ultimately Thames Water customers who pay for the project to get the best value from the project”

# SETTING OUT EXCLUSION ZONES

Following a tragedy on the Crossrail project, the British tunnelling industry has come together to produce a best practice guide on SCL exclusion zone management

SINCE THE INTRODUCTION of sprayed concrete as a means of providing tunnel support we have lived with the ever present challenge of defeating gravity. When the ground conditions, shotcrete mix and physical application all align, sprayed concrete is a highly effective means of placing a tunnel lining. Unfortunately this perfect meeting of constraints isn't always achievable, even with every effort made by the construction team to ensure the highest quality of the lining and the outcome can be collapses of fresh or green shotcrete or the ground it is designed to support.

Teams utilising sprayed concrete have previously managed the process of preventing injury to personnel from falling materials with a number of methods that have had no industry wide adoption or consensus.

The construction teams undertaking the work and exposed to the risks can also be desensitised to the risk and the need for a robust system of prevention that is adhered to.

On numerous occasions I am sure many SCL team leaders have been advised how to manage face access and then have those giving the advice stumped when they watch the work in progress and see the viability of their proposal evaporate. The constantly advancing face and presence of heavy machinery makes a viable solution to controlling access into the area of high risk a challenge that doesn't have an easy fix. A viable solution relies on the cooperation and understanding of all personnel involved in the process from operative to the senior members of the client's team.

The first step to success is communicating the risk, and the reason for operating an exclusion zone. Anyone who has worked in an SCL tunnel will have seen shotcrete falls but still, so often, personnel feel justified in "just popping" into the high risk zone beneath exposed ground or green

**Roger Bridge**  
Roger is a tunnelling manager for Balfour Beatty and former BTS chairman



shotcrete because they think they are helping, saving time, or that it won't happen to them. No one's luck holds out for ever and every time someone enters that danger zone there is the potential that they won't be walking out, however briefly they enter for. It also then creates the additional risk for colleagues or emergency teams wanting to assist them.

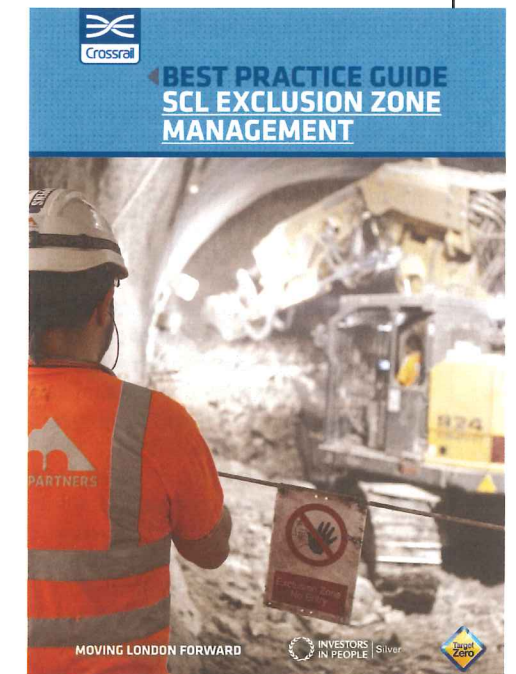
The unfortunate death of Rene Tkacik on a Crossrail worksite made the risk very apparent to everyone and was the catalyst to bring all parties together to agree a unified solution to manage exclusions zones.

The gathering of so many companies and individuals on Crossrail presented an opportunity to develop a document that could become industry wide guidance with agreement from a large percentage of the industry before its publication.

We mustn't forget that with the development of ever more efficient lining designs and the need to verify geotechnical conditions and shotcrete performance and early strength gain essential to maximise productivity and reduce costs it is easy to take the simple option and require personnel to visit the face.

The presence of this guide will remind all that access should be a last resort and alternative means to gather the data need to be adopted rather than the easy one (pleasingly there are plenty of initiatives looking to develop solutions that eradicate the need to access the face).

The document forms a reference to guide and inform future projects



of the issues to be considered when establishing exclusions zones for Sprayed Concrete Lining works. There remains the need for every project to review the specific conditions under which they will operate to ensure that the process is fully applicable to their works. When every scheme is aligned with this process, its application will become second nature to all and not seen as a hurdle to completing the works.

I was pleased to read a short, concise and clear document that is easy for all to follow and understand.

I hope that the document becomes common place on all projects and when it was discussed amongst the British Tunnelling Society committee it was a simple decision to make this document available to all of our members and the wider tunnelling community through our website and the greater the awareness of its presence the greater the chance of the desired blanket adoption.

I am sure that the present review of BS6164 [the British Standard for health and safety in tunnelling] will take note of this document and we are likely to see some of its content appearing in the British Standard in the next revision.

Congratulations to Crossrail and everyone involved with the guide

## 3RD ANNUAL UNDERGROUND SPACE ENGINEERING

20 - 21 JULY 2016 | GOODWOOD PARK HOTEL, SINGAPORE

### KEY BENEFITS OF ATTENDING:

- **Exploring** new ways in utilising underground space and it's engineering complications
- **Discovering** the latest developments: How far has the technology come and it's success factor
- **Assessing** the effect of tunnel excavation works on adjacent structures
- **Exploring** the technical challenges in constructing underground projects and caverns
- **Handling** unique and complex ground conditions
- **Exploring** urban tunnelling and underground expansion

For registration / further details, contact

**Corin Tan**

T: +603 2775 0000 ext. 510 | F: +603 2775 0055 | E: corint@trueventus.com

# EXCLUSION ZONE MANAGEMENT GUIDE

## SECTION A - GENERAL

### Purpose

Falling ground or immature (green) concrete within sprayed concrete lined tunnels is a major risk to personnel working in a tunnel, and the main mitigation measure to prevent injury is the use of exclusion zones for high risk areas.

The purpose of this document is to provide guidance on the consistent application of control measures to be used on Crossrail sites in the management of exclusion and restriction zones around active working areas in tunnels employing the Sprayed Concrete Lining (SCL) methodology. This guidance document has been prepared following discussions within Crossrail, with the SCL contractors and with the designers working on the project.

The guidance provided within this document should not be transferred to other projects without full consideration of the specific risks associated with the ground, methods of working, plant, materials used and the competence and experience of personnel being taken into consideration.

All tunnel working activities shall be carried out in accordance with BS 6164: 2011 'Code of Practice for Health and Safety in Tunnelling in the Construction Industry', and this document discusses supplementary guidance information, which should be followed to assist in complying with the requirement to restrict access for personnel (BS 6164 Table 1) in zones subject to SCL falls.

### Scope

The information provided in this document is applicable to all SCL works on the Crossrail project and has been prepared to establish principles in relation to protecting personnel from falling ground or immature concrete close to the working face. This document relates to all areas of a tunnel where initial and primary linings are being sprayed, including the breakout for junctions and construction of connecting tunnels. The principles listed within this guidance document concerning exclusion zones also apply to the construction of sprayed concrete secondary linings and may be followed with suitable adjustments to consider the larger areas impacted and access routes available.

A reproduction of the recent Crossrail best practice guide for the management of SCL exclusion zones

The information provided here relates only to the management of, and testing for safety related to potential falls close to working areas. Other testing requirements for control of the quality of the works are described within the Works Information and must continue to be undertaken at the frequencies defined.

### Definitions

For the purposes of this document the following definitions shall apply and should be used across the project in all documentation relating to this subject:

Exclusion Zone – an area defined on site where no personnel will be allowed to enter under any circumstances.

Restricted Area – an area defined on site where there is authorised access for defined personnel only, including supervision and engineering teams. Restricted areas may be split into separate areas with the higher number (e.g. Restricted Area 2) being closest to the Exclusion Zone or working face.

Normal access zone – an area defined on site where authorised access through normal tunnel entry procedures is allowed.

### Roles and Responsibilities

The following defined roles should be identified and confirmed at each shift briefing. The decision on who is best placed to take on these roles shall reside with the Principal Contractor responsible for the safety of personnel within the particular work area.

At no time should a person undertaking a task that could distract them from the role in question be in a position named below.

The use of competent deputies and delegation of authority should be established to cover times when the main named responsible person is away from the work area, or will be distracted by undertaking his own defined tasks to complete the works.

### Exclusion Zone Supervisor

Responsibilities include:

- Monitoring and maintenance of the systems in the work place required to define and communicate the limits of the exclusion zone
- Agreeing with the Exclusion Zone Engineer (see below) that an Exclusion Zone can be temporarily or permanently released to a Restricted Area

### Exclusion Zone Supervisor (deputy)

Responsible for undertaking the Exclusion Zone Supervisor's role when nominated by that person, with suitable people identified at the briefing at the start of each shift.

### Exclusion Zone Engineer

In most circumstances this will be the Shift Engineer or his identified deputy for this role, but can be anyone competent at carrying out the appropriate testing. Responsibilities include:

- Performing any specified tests related to the release of an Exclusion Zone
- Monitoring any defined time periods related to the first testing for the release of an Exclusion Zone
- Agreeing with the Exclusion Zone Supervisor (or nominated deputy when acting as the Supervisor) that an Exclusion zone can be temporarily or permanently released to a Restricted Area

## SECTION B - EXCLUSION ZONES AND RESTRICTED AREAS

### Requirements for a defined Exclusion Zone

The following are the minimum requirements that should be in place for an Exclusion Zone and should be communicated to all personnel entering the tunnel and considered on a risk based approach taking due cognisance of the prevailing conditions and methods:

- Defined minimum strength of the last concrete sprayed before an Exclusion Zone may be changed to a Restricted Area. This should be demonstrated by calculation by the contractor's designer, accepted by the Crossrail Project Manager, and shall not be less than 0.25MPa
- Defined time before the strength testing is first carried out by an approved method
- Defined minimum distance from the working face or a defined position at the face. For the Crossrail project this shall not be less than 2m
- A physical barrier defining the boundary between the Exclusion Zone and the Restricted Area at all times except during excavation

### Requirements for a defined Restricted Area

The following are the minimum requirements for a Restricted Area and shall be considered on a risk based approach taking due cognisance of the prevailing conditions and methods. This area should always be as safe as reasonably practical with safe systems of work established for all activities undertaken in this area.

- A visible barrier defining the boundary between the Restricted Area and the Normal access zone
- A minimum length of the total Restricted Area
- A list of personnel entitled to be within each Restricted Area
- A maximum number of personnel normally expected to be within each restricted area during spraying operations
- A maximum number of personnel normally expected to be within each restricted area during excavation operations
- Arrangements to be put in place to allow other personnel to enter a restricted area for a special reason. In some cases this will involve stopping work or restricting plant movement

### Control of Exclusion Zones

The Exclusion Zone will be under the control of the named Exclusion Control Supervisor or his nominated deputy, and under no circumstances should this person be in a position where they could be distracted from this function.

At all times the following must be in place when an Exclusion Zone is in operation:

- A physical barrier between the Exclusion Zone and the Restricted Area at all times except during tunnel excavation
- A clear board or sign explaining the Exclusion Zone limits under particular work activities (see example in Appendix)

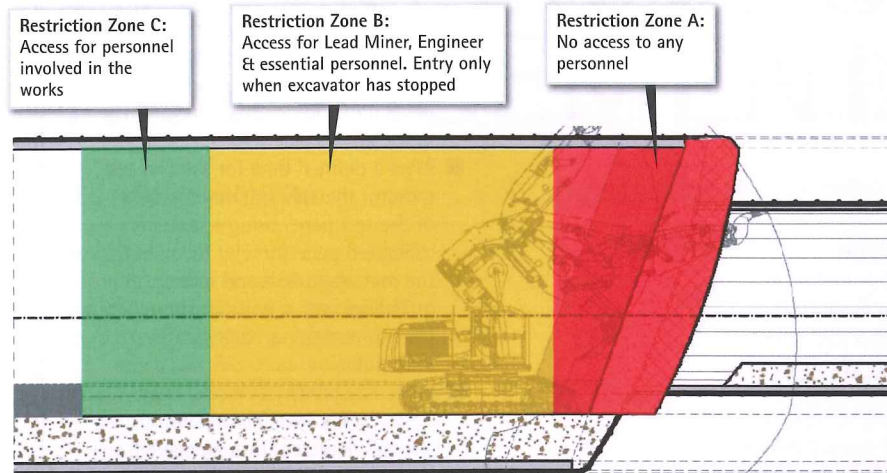
### Release of Exclusion and Restricted Zones

The following process should be followed during working activities

before an Exclusion Zone can be released to a Restricted Area:

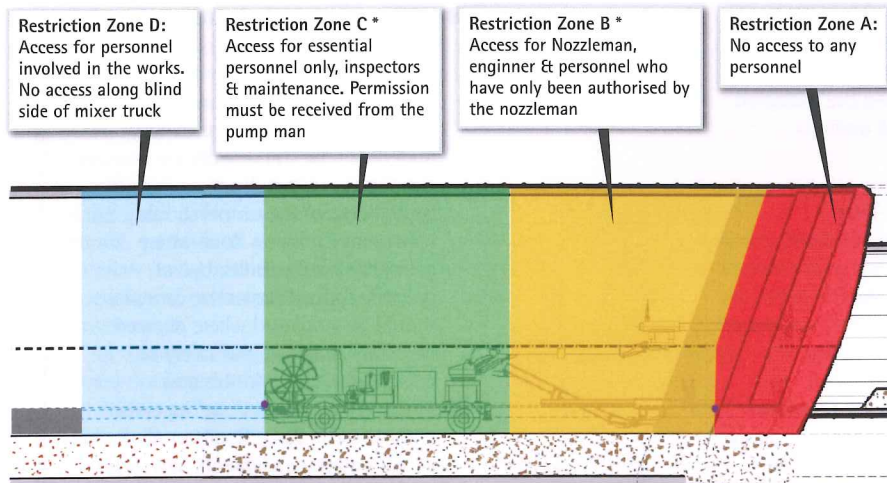
- At the end of spraying activities for the particular advance, spray test panels for strength control testing using percentage dosage of accelerator used in the advance
- After a defined time for the first test, monitor the strength development of the test panel using a properly calibrated penetrometer following the manufacturer's and relevant BS guidelines with a sufficient number of tests to remove variability concerns in the results
- When the panel test results have achieved the specified minimum strength level, confirm agreement between the Exclusion Zone Supervisor and Exclusion Zone Engineer that these requirements have been met and it is acceptable to undertake penetrometer tests on the profile of the last sprayed concrete
- Undertake strength development test, using a penetrometer, of the last sprayed profile to confirm that this has achieved the minimum strength specified. This test should be undertaken by standing as close to the side wall as possible. The central area of the tunnel should remain an Exclusion Zone where geometry (size) permits. Use of specially formed protective canopies should be employed where deemed necessary to ensure the safety of personnel working in this area
- When the Exclusion Zone Supervisor and Exclusion Zone Engineer agree that all minimum requirements have been met, the Exclusion Zone Supervisor may release the zone to a Restricted Area for defined operations within this area. All works within this area should be undertaken within 2m of the side wall with the central section of the tunnel (i.e., under the crown between approximately 10 o'clock and 2 o'clock) remaining an Exclusion Zone where tunnel geometry allows. Use of specially formed protective canopies should be employed where deemed necessary to ensure the safety of personnel working in this area
- Where tunnel geometry has allowed a central area Exclusion Zone under the crown to remain, release of the full face area shall only be permitted when:
  - All the above criteria for the release of an Exclusion Zone have been met
  - Additional criteria set by the contractor and accepted by the Crossrail project manager for strength gain or time delay have been met

### Mucking Cycle



Restriction Zone B \* No access on blind side of excavator. No entry passed dumper being loaded  
 Restriction Zone C \* Escorted visitors may only enter restriction zone C only if deemed suitable by their escort

### Spraying Cycle



Restriction Zone A \* Under no circumstances must this area be entered until checks on a panel have been carried out and entry agreed as per the General SCL Methodology WMS.  
 Restriction Zone C\* Is applicable when any part of the spray is above axis level. When spraying only below axis level Restriction Zone B extends to the face and there is no Exclusion Zone A  
 Restriction Zone D \* Escorted visitors may only enter restriction zone D only if deemed suitable and safe by their escort

A Restricted Area may be released to a Normal Access Zone when:

- The exclusion zone has advanced or been removed so that the minimum length of the Restricted Area(s) is not breached
- The Exclusion Zone Supervisor or his deputy has agreed that a change in status is acceptable

#### SECTION C - ADDITIONAL INFORMATION

##### Communication

The following methods should be used to communicate the necessity and operation of Exclusion Zones and Restricted Areas to all personnel within the tunnel whether working in the tunnel for any reason, or a visitor. All communication should be through properly inducted and competent personnel:

- All inductions

**Above: Zones applicable to the two cycles: mucking and spraying**

*This guide was produced by collaboration between Cross-rail, BFK, BBMV, DSJV, Costain-Skanska and Hochtief-Murphy*

### External standards

**BS 6164:2011** Code of practice for health and safety in tunnelling in the construction industry

### Phonetic alphabet

A - Alpha	J - Juliet	S - Sierra
B - Bravo	K - Kilo	T - Tango
C - Charlie	L - Lima	U - Uniform
D - Delta	M - Mike	V - Victor
E - Echo	N - Nov	W - Whisky
F - Foxtrot	O - Oscar	X - X-ray
G - Golf	P - Papa	Y - Yankee
H - Hotel	Q - Quebec	Z - Zulu
I - India	R - Romeo	

Numerals should be spelled out, not given as whole numbers: 121 is 'one-two-one', not 'one hundred and twenty one'

- Toolbox talks
- Shift briefings to operatives and staff working in the tunnel
- Site visitor briefings to all other visitors
- Record site specific requirements on RESS where appropriate and would not affect clarity of RESS

Visible and protected (e.g., laminated) display boards depicting the Zones and Areas clearly and graphically. These boards should be at least A1 size and located close to the boundary between the Exclusion Zone and the Restricted Area, and at the entry to the Restricted Area.

At any time that an area changes from an Exclusion Zone to a Restricted Area, or from a Restricted Area to an Exclusion Zone, the Exclusion Zone Supervisor must ensure that all barriers are appropriately set-up and that personnel undertaking tasks close to the exclusion zone are notified and aware.

#### Further Measures

CCTV monitoring systems at the face should be used at all SCL locations unless agreed by the Crossrail project manager and Contractor project director that they are not appropriate in that location. The following additional measures should be considered and adopted where appropriate:

- The use of thermal imaging technology to support the strength testing and time restrictions and to search for local cold spots in inaccessible areas that can not be examined by penetrometer testing
- Traffic light systems or boards to reinforce the physical barriers used, particularly at the boundary between the Normal Access Zone and the Restricted Area

**OSTU STEEL AND FORMWORK**  
 www.tunnelschalung.at

**OSTU - STETTIN** Hoch- und Tiefbau GmbH  
 Münzenbergstraße 38 / A - 8700 Leoben  
 Tel.: ++43 (38 42) 4 25 23  
 Fax: ++43 (38 42) 4 25 23 -142  
 E-Mail: schalungsbau@oestu-stettin.at

CONSTRUCTION UNLIMITED

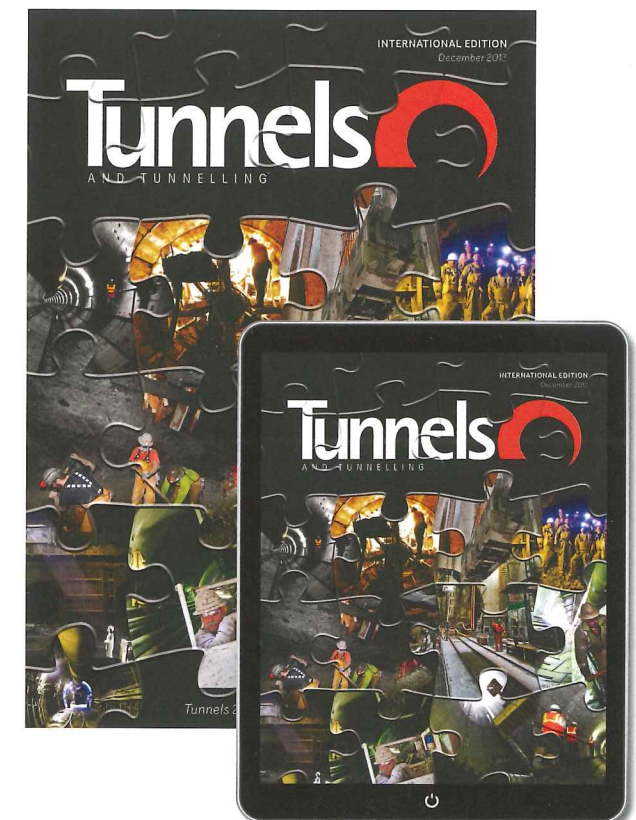
QUALITÄTSMANAGEMENTSYSTEM  
 ZERTIFIKAT  
 oas

# Tunnels

AND TUNNELLING INTERNATIONAL

## 2016 features schedule

- August**  
Regional focus: Middle East and Africa  
Tech: Education/training
- September**  
Regional focus: Europe  
Tech: Modelling
- October**  
Regional focus: North America  
Tech: Sprayed concrete
- November**  
Regional focus: Asia  
Tech: Extreme site conditions
- December**  
Regional focus: Europe  
Tech: Precast



For advertising opportunities please contact **Tom Willard** on +44 (0) 203 096 2608 or email [twillard@tunnelonline.info](mailto:twillard@tunnelonline.info)

Your customers take chances because they're insured...

...so why make your business strategy a leap of faith?

Global Insurance intelligence for Life, Non-Life and Reinsurance to drive growth and minimize risk

The Insurance Intelligence Center is an annualised service offering clients an understanding of key industry trends and competitor dynamics for more than 180 insurance markets and 8,000 reinsurance players globally.

Real-time monitoring, research and analysis means that our data is timely, accurate and relevant.

For further information visit [www.insurance-ic.com](http://www.insurance-ic.com) or contact us on:

London - +44 (0) 203 096 1977  
Sydney - +61 2 8076 8800  
New York - +1 646 395 5465

or by email at: [sales@insurance-ic.com](mailto:sales@insurance-ic.com)

# HAWKS NEST DISASTER

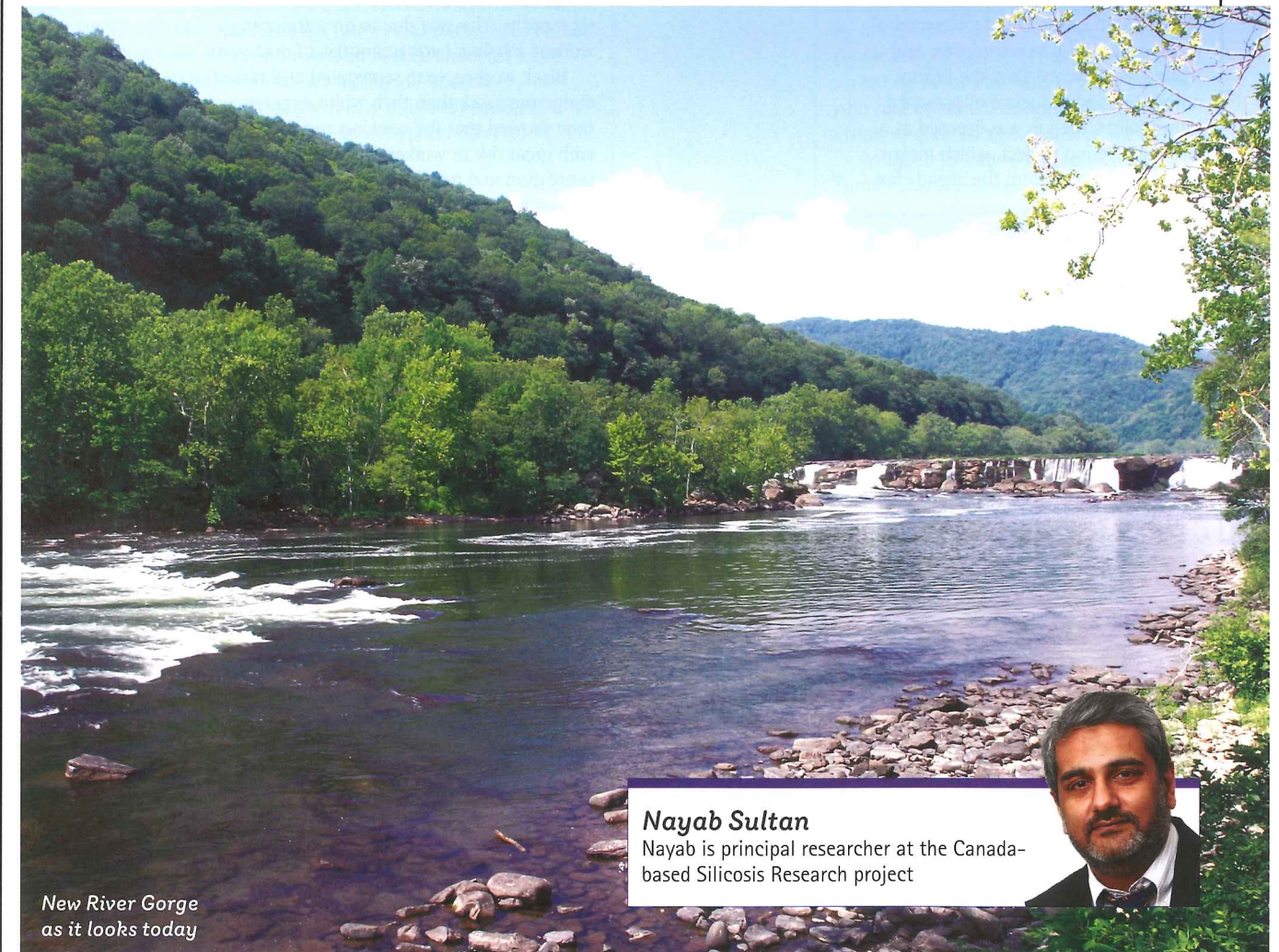
Nayab Sultan, Doctoral researcher at *Silicosis Research* gives this insight into the Hawks Nest Incident, considered by some to be the worst industrial disaster in US history

IN THE LAST 200 years we have seen some extraordinary engineering achievements that have pushed the envelope of engineering excellence to new heights. These range from the building of the Panama Canal, Karakoram Highway to a raft of tunnels and bridges across the globe.

Along with such advances there have been consequences of untold human life loss and suffering amongst the often transient migrant workforces that contributed towards these projects quite often with their life or health. One project that has been consigned to infamy is the construction of the Hawks Nest Tunnel by Union Carbide Chemicals Corporation in the US in the 1930s.

Considered one of the worst industrial disasters recorded in recent history this relates to a three-mile (4.8km) stretch of 30ft (9.1m) diameter tunnel used to divert a section of the New River downstream through Gauley Mountain in Gauley Bridge - a scenic cliff in the New River Gorge, in West Virginia.

Drilling through three miles of solid rock, the Hawks Nest Tunnel was viewed



New River Gorge as it looks today

**Nayab Sultan**  
Nayab is principal researcher at the Canada-based Silicosis Research project

### Timeline

- 1930 - Construction begins
- 1930 - Workers start to get acute silicosis
- 1933 - Great trial starts against contractors
- 1934 - Another great trial starts against contractors
- 1936 - Union Carbide starts using power from tunnel
- 1936 - Hearings in US House of Representatives attribute 476 deaths
- 1986 - Study by Cherniack estimates 764 deaths due to silicosis from construction works

as a business-critical requirement for the Union Carbide's plant, located nearby in the town called Alloy for the purpose of steel alloy production.

#### AVOIDING RED TAPE

The tunnel was constructed to serve as a hydroelectric water diversion tunnel. At the time of the conception of the project the US was in the midst of a major economic crisis known as the Great Depression, as a result there was a great impetus to keep the wheels of the economy turning. Men desperate for work flocked to the area, the majority being African Americans from the southern states. Due to commercial pressures to finish in record time and fearing interference from the federal authorities and influence of powerful industrialists, the job was licensed as a civil engineering project, which meant it became exempt from the already lax

Table 1.

Type of Material	Crystalline Silica Found (%)
Tripoli	95+%
Sandstone	70 - 90%
Foundry Moulding Sand	Up to 90%
Plastic Composites*	19 - 90%
Road Rock	Up to 80%
Concrete / Mortar	25 - 70%
Shale	40 - 60%
China Stone	Up to 50%
Granite	20 - 45%
Tile	30 - 45%
Slate	20 - 40%
Clay	Up to 40%
Brick	Up to 30%
Ironstone	Up to 15%
Basalt / Dolerite	Up to 15%
Limestone	Up to 2%
Marble	Up to 2%

Source: Author  
\*silica used in composite materials or fillers

working conditions, and workers' health and safety legislative requirements such as wet drilling in mines and tunnels at the time.

In order to undertake the works, contractors were selected by Union Carbide. One of the two was a corporate entity created solely by Union Carbide for the works - New Kanawha Power Company - and Rinehart & Dennis of Charlottesville, Virginia.

During the initial scoping of works, core samples taken showed that the majority of the tunnel would be dug through a particularly high grade of silica bearing sandstone. This would later go on to become extracted by enlargement of the tunnel by a third even though Union Carbide claimed they were unaware of the presence of silica also known as silicon dioxide.

At its height of construction, between 1933 - 1934, an estimated 5,000 workers were involved in a range of activities on site. The vast majority of the black workers were tasked to do the dangerous jobs including working at the drilling face, with a small community of locals working in ancillary tasks. The combination of large work crews drilling and blasting underground in confined spaces, lack of dust suppression, presence of gas fumes, inadequate ventilation and no personal respiratory equipment were all significant contributory factors of high levels of exposure. It is thought that within two years of the initial groundbreaking in April 1930 that workers started to succumb to the effects of an incurable disease of the lungs - acute silicosis.

In all, an approximate 2,982 men worked underground in drilling and blasting, the majority of who worked 10-hour shifts six days a week. At any one time an estimated 500 men were underground with 35 at the drilling face. Of these 40 per cent worked more than two months and only 20 per cent more than six months. This was due to an astonishingly high percentage of workers inhaling large quantities of dust particularly silica dioxide.

Black workers were segregated and tasked to do more dangerous work than their white counterparts. Accounts from the time showed that the working conditions were considered atrocious with great risk to workers from multiple hazards including poor ventilation and gas fumes filling the worksite. Dust made visibility challenging and the lack of clean unpolluted air coupled with strenuous work meant workers would have to inhale more deeply thus taking in more inorganic dusts, including silica dust, deep into their lungs resulting in breathlessness, cough, fever and cyanosis (bluish skin).

#### VILLAGE OF DEATH

Local armed henchmen under the control of the Sheriff forced workers from their camp above the mountain entrance known as the 'Village of Death' and forced them out of bed to work at gun point according to one Congressional Hearing eyewitness. This witness spoke of fear and intimidation faced by many and those who were too sick to work were forcibly evicted from the site even when they could hardly walk. This was also the same fate that awaited those who started to manifest any of the typical symptoms of sickness. The transient nature of the workforce made it difficult to determine accurately exposure and consequences as many would either leave after becoming sick, be pushed out of town or simply die. Even with such harsh working conditions the tunnel broke through within 17.5 months, 10 weeks ahead of schedule, in September 1931.

Although the exact number of deaths is difficult to gauge, some light was shed on this by research conducted by epidemiologist Martin Cherniack in 1986, which showed the approximate figure to be 764 (581 being African American workers) from Acute Silicosis and associated conditions - a marked difference to the official count 476 presented to the US House of Representatives in 1936. This only became a political issue after national news stories were run for several weeks describing the plight of the workers. At this stage their conditions and unfolding tragedy became public

Table 2.

Type of Silicosis	Exposure	Latency before symptoms develop
Acute Silicosis*	Heavy exposure over short periods	2 weeks - 5 yrs.
Accelerated Silicosis**	High exposure over a period of time	5 - 10 yrs.
Chronic Simple Silicosis	Relatively low to moderate exposure over a long period of time	10+ yrs.

Source: Author  
\*acute silicosis was the primary form recognised in Hawks Nest but either of the other two forms could also have been possible.  
\*\*complicated silicosis associated with accelerated silicosis occurs as a result of severe scarring and can be complicated by other lung diseases such as TB, fungal infections and certain autoimmune diseases

knowledge. The numbers could have been far higher, possibly in the thousands, however with many workers leaving the county and the state after becoming sick or completion of their specified work it was difficult to gauge. Suggestions of mass burials could not be substantiated although many were buried in unmarked graves near the mouth of the tunnel. It should also be noted that it was also not unreasonable for workers with symptoms related to silica dust exposure to be misdiagnosed with other respiratory conditions.

Based on Cherniack's research there were 135 more deaths of white people in Fayette County between 1931-1937 compared to other neighbouring counties in the state of West Virginia. He was able to attribute these deaths to the tunnel and calculated that 63 per cent of local white men who worked in the tunnel for more than two months died within six years of acute silicosis.

One unnamed worker stated the reality is a harsh contrast: "men die in the camps, under rocks and everywhere else".

#### THREAT ANTICIPATION

Union Carbide continued to deny any knowledge or wrong doing claiming they were unaware of the presence of adverse working conditions and that the tunnel had not contributed to disease and death. In one statement by the chief engineer he claimed that he never saw dust or at least enough to say that it

### Hazard and precautionary statements

#### GHS Hazard Statements

- H350: May cause cancer [Danger Carcinogenicity - Category 1A, 1B]
- H370: Causes damage to organs [Danger Specific target organ toxicity, single exposure - Category 1]
- H372: Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure - Category 1]

#### Precautionary Statements

- P201: Obtain special instructions before use
- P202: Do not handle until all safety precautions have been read and understood
- P260: Do not breathe dust/ fume/ gas/ mist/ vapours/ spray
- P264: Wash thoroughly after handling
- P270: Do not eat, drink or smoke when using this product
- P281: Use personal protective equipment as required
- P307+P311: IF exposed: call a POISON CENTER or doctor/physician
- P308+P313: IF exposed or concerned: Get medical advice/attention
- P314: Get medical advice/attention if you feel unwell
- P321: Specific treatment (see label)
- P405: Store locked up
- P501: Dispose of contents/container to ...

was dusty. The corporate line remained that the threat of silicosis could not have been anticipated even though it was a recognised occupational hazard during that period. The companies claim was classed as duplicitous by Cherniack who stated they were fully aware of the conditions and in fact used the silica they removed and that it was common knowledge in the 1930s at the time that silica dust could be adequately controlled with adequate ventilation and moisture at the drill site. To further close the argument on lack of awareness the company provided its own engineering staff at the site with respiratory protective equipment.

After a high degree of controversy across the two high profile trials (1933, Fayetteville and 1934, Charleston) 538 claims were filed against the two contractors, however with evidence of jury tampering, political interference and generous compensation made to plaintiffs' attorneys the settlement came to a scanty USD 200,000 with individual awards of compensation ranging from a meagre USD 30 to USD 1,600. The controversy of the Hawks Nest Disaster was quickly forgotten by the press in fear and danger of stepping on the toes of powerful industrialists, according to senator Holt of West Virginia who had become a staunch advocate for action to curb silicosis deaths at the site.

Assigned to infamy the Hawks Nest Tunnel Disaster is now, as it was back in the 1930s, an important labour culture benchmark alongside Delamar, Nevada, also known as 'Ghost Town', which went on to be known as the 'widow maker' due to quartzite causing silicosis amongst its transient miners in the later 1800s.

The tunnel continues to operate and provide power to the current owners of the plant in Alloy, West Virginia.

#### CHANGE ON THE HORIZON

The Obama Administration has finally introduced stricter controls in the form of the 'Silica Rule' as a result of decades of political wrangling. OSHA states that the consequences of exposure have been known for millennia and that the new rules will protect approximately 2.3 million workers exposed in the US from harmful levels of airborne silica dust and the net savings of USD 3.8bn - USD 7.7bn, which in times of fiscal austerity will present huge benefits to the national economy.

What this means in terms of industry requirements is what was known even at the time of the Hawks Nest Disaster - using wetting techniques to suppress dust, capturing dust with vacuums or other dust capturing devices, and not

to place dependence upon the use of respiratory protective equipment, which may not be sufficient as a singular control measure, according to OSHA. The Silica Rule will be phased in during 2017 even though according to the Centers of Disease Control (CDC) silicosis is relatively rare in the US even though this remains the world's most common occupational lung disease.

### SILICA DUST AND SILICOSIS

In the Hawks Nest Disaster reference was made to Acute Silicosis and other diseases. But the questions are more basic than this starting with 'what is silica dust'.

Silica occurs in three forms: crystalline, microcrystalline (or cryptocrystalline) and amorphous (non-crystalline) and is from the Latin word Silex or flint.

In the case of crystalline silica there are seven further forms (polymorphs) depending upon the temperature of formation. The three main polymorphs are quartz, cristobalite and tridymite. It is estimated that quartz is the second most common mineral in the earth's crust after feldspar.

Silica is, as in the case of Hawks Nest was in the form Silicon Dioxide (another name of silica), a chemical compound that had been used in various applications for thousands of years. Silica is commonly found in nature as quartz and is a major constituent of sand as well as in stone, rocks and clay. When cutting or drilling the respirable crystalline silica dust becomes airborne and can be breathed in causing hundreds of thousands of deaths worldwide. It is found mostly in mining and purification of quartz and is a recognised human carcinogen. Agricola 'the father of mineralogy' from the 16th century writes about problems from dust inhalation in miners.

The mineral quartz, cristobalite and tridymite are crystalline forms of silicon dioxide with quartz is simply yellow sand and is found in most rocks but particularly in sandstone and granite. Not all forms of silicon dioxide are as harmful such as amorphous silica such as diatomaceous earth, which is not known to cause either silicosis or lung cancer based on current research.

Silica dust is harmful on inhalation but the size of the particles is important with larger particles generally being stopped in the nose or the upper airway. It is the finer smaller particles which can make their way down into the lower levels of the lungs where gaseous exchange takes place where it becomes hazardous to human health causing scarring and chemical changes after being deposited in the lungs. Unfortunately the body's natural defences

such as mucous and coughing prove to be relatively ineffective in expelling this foreign dust from the body.

In the case of Hawks Nest the particles were fine coupled with particularly high silica content sandstone, which can contain 70 – 90 per cent, which is one of the highest ranges of materials. Information is provided in Table 1 from HSE data provided through the No Time To Waste Campaign.

Silicosis a shortened name for Pneumonoultramicroscopic-silicovolcanoconiosis and also over history had names such as Miner's Phthisis, Grinder's Asthma, Potters' Rot and many occupational variances. It is also a type of Pneumoconiosis meaning it is a disease of the lungs due to inhalation of dust, resulting in inflammation, coughing, and fibrosis.

Table 2 gives a generalisation of the exposure and the period before symptoms may start to manifest:

In Hawks Nest the majority of references relate to those with Acute Silicosis, which can happen as we saw in a very short period of time, in some cases simply months. Research generally places the scale of about two to 18 months but in the case of Hawks Nest the exposure was significant.

With prolonged exposure over a period of time usually 10-15 years would lead to chronic form of Silicosis, which many could have had but were no longer available due to be the migratory nature of the workforce.

Silicosis is only one condition that can occur from exposure to respirable crystalline silica dust and the others could also have been present amongst the Hawks Nest workers other than solely Silicosis:

- Chronic Bronchitis
- Lung Cancer
- Pulmonary Fibrosis
- Rheumatoid Arthritis
- Scleroderma
- Systemic Lupus Erythematosus
- Autoimmune Antibodies (Positive ANA, Anti-DNA, RF, others)

And also possibly:

- Chronic Obstructive Pulmonary
- Oesophageal Cancer
- Glomerulonephritis
- Sarcoidosis
- Vasculitis
- Dermatomyositis
- Granulomatous Disease (Liver)
- Immune Suppression
- Mesothelioma

Below: Historical photo of the excavated tunnel

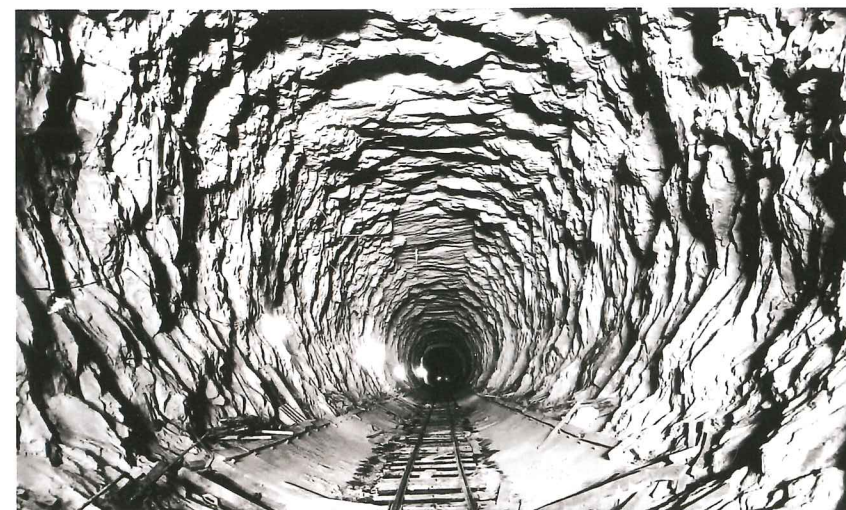


Table 3. Some other projects assigned to history for worker deaths

Project	Years / Period	Estimated deaths	Primary causes
Panama Canal, Central America	1880 – 1914	30,000 (*25,000)	Accidents and Tropical Diseases *Yellow Fever and Malaria
White Sea-Baltic Sea Canal, Europe	1931 – 1933	12,000 – *25,000	Accidents
'Death Railway' Burma-Siam Railway, Asia	1942 – 1943	7,000 – *70,000	Tropical Diseases and Malnutrition
Karakoram Highway, Asia	1959 – 1978	892 Official Record	Rock fall / landslides
Aswan Dam, Africa	1960 – 1970	500 – *550	Lack of Safety Equipment
Hawks Nest Tunnel, America	1930 – 1934	476 – *1000+	Respirable Crystalline Silica Dust exposure causing Silicosis
Hoover Dam, America	1931 – 1935	96 Official Record	'Industrial Fatalities'
Los Angeles Aqueduct, America	1908 – 1913	43 Official Record	Accidents
New York City Third Water Tunnel	1970 – Present	24	Accidents
St. Gotthard Tunnel, Europe	1969 – 1980	19	Accidents

Source: Author

\*various conflicting reports suggest higher numbers however each various widely depending upon official and unofficial sources based on discrepancies in reporting at the time

- Myelodysplastic Syndrome (pre-Leukaemia)
- Pancreatic Cancer

Based on the above known conditions associated with silica dust exposure it is possible there could have been far more many conditions and workers who suffered as a consequence of their exposure at Hawks Nest other than just acute silicosis.

As a disease it is possible to diagnose using patient history, chest x-rays and also ruling out other possible underlying illnesses that may display similar symptoms such as pulmonary oedema, pneumonia and TB (tuberculosis). It is interesting to note that the Hawks Nest disaster was some 85 years ago but the same misdiagnosis remains even now around the world. There is no known cure and some old myths such as inhaling aluminium dust have their own problems of exposure. The current options relate to alleviating the symptoms and avoiding complications.

Prevention is the best form of protection against silicosis and other illnesses by either complete elimination of the silica dust hazard or by introducing suitable engineering controls such as dust control strategies using dry air filtering and water spray where dust emanates. That said each worksite needs to have a comprehensive review of the hazards (risk assessed/hazard analysis/field level hazard assessment/job safety analysis – whatever technique is used) and establish suitable and effective risk control measures such as development of an ECP – exposure control plan – coupled with a health surveillance program for all those exposed to respirable crystalline silica (RCS) dust based on local legislative requirements relating to workplace exposure limits/occupational exposure limits.

### References

- Cherniack, Martin G. "Hawks Nest Tunnel Disaster." e-WV: The West Virginia Encyclopaedia. 04 June 2015. Web 13 April 2016
- Allan M. Brandt (1989). Review of Exploring the Dangerous Trades. Reviews in American History 17(1):101-107
- GBD 2013 Mortality and Causes of Death, Collaborators (17 December 2014). "Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013" Lancet 385: 117-71

### OTHER LOSS OF LIFE

It is interesting to note that Union Carbide through the Union Carbide India Limited UCIL also ran the site in Bhopal in which Methylisocyanate (MIC) was accidentally leaked from the plant and the gas made its way down into the adjoining shanty resulting in an estimated 5,200 deaths and thousands exposed to life changing disabilities.

With all the technological advancements made many large scale projects still under construction continue to have a number of fatalities, which continues to rise even with advances in knowledge and technology.

Even with silica dust being known to be harmful to human health for many centuries and history showing a litany of disasters the menace of silica dust and threat of silicosis continues to loom over workers. With current estimates of workers exposed ranging from 500,000 in the UK, 5 million in the EU, 2.2 million in the US, 10 million in India and an astounding 23 million in China. In terms of deaths this is in an estimated range of 800 in the UK from lung cancer, with 7,000 cases of lung cancer across the EU due to silica dust.

It is important to remember that silica dust can be controlled and silicosis can be avoided, yet even in 2013 there was an estimated 46,000 deaths worldwide from this totally preventable disease which continues to cause terrible suffering globally to millions ☹

### Useful links

[www.silicosisresearch.ca](http://www.silicosisresearch.ca)  
[www.silicahazard.com](http://www.silicahazard.com)

## Sp SPECIALIST PLANT

Specialist Plant designed and provided the ventilation scheme for the tunnelling works at the new Astra Zeneca Headquarters in Cambridge. The system was highly effective and kept dust levels when spraying well below acceptable levels when spraying shotcrete. The fact that Specialist Plant designed the system was invaluable because they were able to check and re-design the suitability of the system when changes to construction methods were made. //

- Lloyd Rew,  
Construction Manager, Skanska



Living Incident Free Everyday

The most effective  
**VENTILATION  
DESIGNS &  
DUST CONTROL  
SOLUTIONS**

across the Crossrail  
works

Call: 01234 781 882  
Visit: [www.specialistplant.co.uk](http://www.specialistplant.co.uk)



### VENTILATION FAN HIRE & ENGINEERING SOLUTIONS

We supply robust ventilation systems to suit any tunnelling or civil engineering application. Axial fans, super-silenced fans, centrifugal fans, jet fans, dust extractors in addition to ventilation system design.



Leading tunnelling equipment hire supplier in the uk!

- **Monitoring and Control**
- **Communications**
- **Collision Avoidance**
- **Asset Tracking**
- **Personnel Tracking**



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

UK: +44 1908 691 685

US: +1 276 988 5505



# CULTURE SHIFT

HEALTH AND SAFETY is becoming more a fact of modern life. The construction industry in particular is under increasing scrutiny; the pressure to conform to regulations is strong. But there are some aspects of health and safety that cannot be improved purely through legislation and directive. One of the main such areas is behavioural safety.

Speaking to Tunnels and Tunnelling earlier this year (see Tunnels and Tunnelling International, March 2016, pp. 20-24) Bob Ibell of London Bridge Associates said that one of the areas in which the industry has taken a backwards step in his career is that there is less of a voice speaking out for the labour force compared with earlier days. The responsibility for thinking about and looking after the workforce has moved downwards, and with main contractors not particularly interested (as a rule), the less-powerful subcontractors have to step in.

In British subcontractor Joseph Gallagher's (JGL) case, as far as behavioural health and safety is concerned, they have,

#### NEED FOR CHANGE

In early 2014 a machine driver performed an operation he was not asked to do, without a method statement detailing how to do it. As a result of the decision, another worker was badly injured and the company decided it needed to do things differently.

Up until this point, according to JGL group managing director Steve Harvey, the company had been led by whichever main contractor it was working for. JGL would get involved in everyone else's health and safety as well as the accepted behavioural safety programmes. However, the decision was made to develop its own programme rather than using a main contractor's.

The principle is training the workforce to have 'leaders' in among the labour, carrying out the work while taking responsibility for their own health and safety, and also to develop a culture of looking after each other.

#### GATHERING DATA

The first step was to identify the needs of the company. JGL hired a behavioural safety specialist called Alkoomi. Alkoomi started the process by performing a cultural survey of all employees. This is an anonymous process that involves paper-based questionnaires to individual interviews. A report is produced that demonstrates what people think of the business.

"Coming from the mining industry, which is culturally quite an aggressive environment, this came out probably slightly better than we thought," muses Harvey.

Some 17 key points came out of this cultural survey, which included comments such as "method statements were being prepared by engineers or managers who don't really understand the key points of the work". According to Harvey, the comments were pretty much what might be expected from a construction subcontractor's workforce, but having gotten everything out in the open through anonymous comments, the company could move forward with plans.

#### DEVELOPING A PROGRAMME

Firstly a leadership team was put together from JGL employees across the business, from site workers to directors, and set aside to be independent from the financial and day-

A jobsite incident led subcontractor Joseph Gallagher to the conclusion that piggy-backing on customer behavioural health and safety schemes would no longer be sufficient. **Alex Conacher** speaks to managing director Steve Harvey about the process the company went through to implement its 'Living Incident Free Everyday' (LIFE) scheme

to-day control of the business. It exists solely to focus on the culture and approach to health and safety.

A bespoke programme was then developed with the help of Alkoomi to educate the people, it is built around them and what Harvey calls "exceptional leadership". The chosen employees also go through a course to teach them how to train others. These people then train the wider company in behavioural workshops that all employees then have to go through.

"The workshops are led by individuals who have shown an aptitude for leadership," says Harvey. "It is quite a powerful thing to see senior managers in a business taken through a training course by a concrete pump operator, a labourer, or a machine driver just because he was seen to have this aptitude. It relies a lot on mutual respect.

"When we first put the programme in, I went out with Joseph Gallagher himself and we went to see every person in the business. This meant going up and down the country, seeing 100 people at Bond Street or two people at a site at a motorway service area. But we still leave the direction of the safety side of the business to the LIFE leadership team.

A lot of businesses have behavioural safety, but what is important is being relentless with it according to Harvey. As a construction company, there

#### Alex Conacher

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



is not much difference in what JGL would require compared to any other programme. But as a subcontractor – a hands-on company with a relatively large number of direct employees – it has a lot of impact on site if the company has its own programme. The company has its own policy rather than leaving it to the main contractor to try to control the way they work.

“They are our people doing the work, and the company’s reputation lives or dies on the back of what they do,” says Harvey.

#### IMPLEMENTATION

There is a workforce engagement half-day course which has a maximum of ten people, given by JGL workers. At the end of the workforce engagement course, employees are asked to commit to a pledge, and they write down their own personal safety commitment. Some are not interested in doing this, but according to Harvey in those cases the workers are asked to leave the business. New employees are also told, prior to any other discussions, about this requirement and if they are not prepared, the interview stops there.

There are also monthly LIFE meetings that involve the leadership team going through everything that happened in the previous month. It starts with a chance for everyone to give a general feel for how the last month went, before looking at any data, numbers or incidents. Each worksite has representation at this leadership meeting.

“You need to be relentless in pursuing this and staying on top of it. And people have seen it as a very positive thing. Certainly our performance from a health and safety point of view is improving. What we were keen to do was not set any unrealistic targets. We just say our aim is to send everyone home safely at the end of the day, and hopefully we can achieve this.

“We have setbacks, we have had a few incidents since we started, but hopefully this gets fewer and fewer. The important thing is not to throw up our hands when something goes wrong – we say ‘tomorrow is another day’ and not spend too long on mistakes.”

#### INDUSTRY REACTION

Regarding main contractor response, Harvey says it has been positive; that they’re pleased to see a subcontractor taking the initiative.

“It makes their lives a bit easier if they know a subcontractor has the same drive they have. I’ve not come across anyone who sees it as a negative of



Above: Joseph Gallagher has developed the new safety culture since 2014

course. And I’ve always been able to sell JGL as a technically competent business, now I want to sell it as the safest.

“Things are changing. Recently we secured the Bank Station contract in London for Dragados. We were not even talking about price with them at the beginning of negotiations; it was all about how to keep the men safe. It is that significant a factor. There are incentives within the contract around retention of people, safety performance, safe delivery. But to be frank it’s about having a consistent workforce, it’s about having the right leaders on the project, and it’s about working collaboratively as a team to make sure the primary goal on a given day is going to be safe. And that’s essentially what we do with it.

#### FINAL THOUGHTS

“Dragados appears to be a main contractor that wants to be different and are looking for the right way to go. But a lot of contractors are still looking for the cheapest price. But the way to a safe industry is to ensure you have the right people doing the work. And it does come with a price.

“Having said that, if you’re not working safely it ends up costing a lot more, but it’s too late by that point in time. I’d like to think we have the right strategy”

## Joseph Gallagher Ltd

SPECIALIST CIVIL ENGINEERING CONTRACTORS

#### CIVIL ENGINEERING

Reinforced concrete, Basements & Underpinning, Groundworks and Structural Alterations & Refurbishments.

#### TUNNELLING

Shaft sinking, Escalator construction, SCL, Hand & Shield driven tunnels, Pipe Jacking and Microtunnelling

#### JOHNSTON TRENCHLESS SOLUTIONS

HDD, Pipe Burst, Auger Boring, Microtunnelling and Shaft sinking.

#### JGL FOREIGN DIVISION

Microtunnelling, Shaft Sinking, HDD & Pipe Jacking internationally.



WWW.JOSEPHGALLAGHER.CO.UK  
T: 01375 672 070

## VIP | TUNNEL SEGMENT GASKETS

Our extensive range of glued in place, hydrophilic and cast-in gaskets are selected as original equipment by many of the leading Global concrete segment manufacturers.

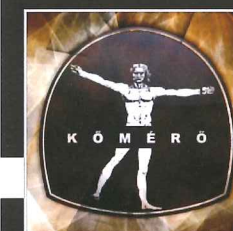
#### NEW FOR 2016:

our patent (pending) corner jointing system for cast in TSGs is designed specifically to eliminate corner point loading – often the cause of cracked and damaged segments.



## VIP | GLOBALLY APPROVED SEALING GASKETS

Tel: +44 (0)1480 411333 Email: sales@vip-polymers.com www.vip-polymers.com



Science-based solutions for practical problems

Kómeró (RockStudy) Ltd.

www.komero.hu

- Geotechnical assessment and classification
- In situ measurements and monitoring
- Consulting and Engineering
- Laboratory services

komero@komero.hu

Science of depth, depth of Science



Table 1. Material properties of intact rock

Rock class	UCS <sub>mass</sub> [MPa]	E <sub>mass</sub> [GPa]	μ <sub>mass</sub> [-]	Y <sub>mass</sub> [kg/m <sup>3</sup> ]	mb [-]	s [-]	a [-]
I.	15,72	38,30	0,312	2606,4	3,8850	0,0151	0,5024
II.A.	11,94	30,94	0,321	2574,7	3,2677	0,0088	0,5034
II.B.	7,99	21,14	0,335	2528,9	2,5467	0,0041	0,5056
III.	4,64	11,73	0,353	2469,3	1,8406	0,0015	0,5104
IV.	2,33	5,70	0,375	2399,4	1,2578	0,0005	0,5214
V.	0,81	2,70	0,401	2312,2	0,7818	0,0001	0,5522

Source: Authors

Table 2. Material properties of rockbolts

Property	Value
Diameter in mm	32
Tensile capacity, F <sub>y</sub> in kN	246
Tensile yield strength, f <sub>y</sub> in N/mm <sup>2</sup>	500
Modulus of deformation, E <sub>s</sub> in GPa	200
Grout cohesive strength kN/m	246
Grout bonding stiffness in kN/m/m	2,5×10 <sup>4</sup>

Source: Authors

When tectonic features such as minor faults (with thickness significantly lower than the tunnel diameter) dominate the behaviour of the rock mass, the so-called stress reflection phenomenon occurs. This means that the fault zone behaves similarly to a mirror, with the stress redistribution pattern “reflected” on the fault zone and the same pattern “shadowed” on the far side of the fault. Stress reflection is caused by the low shear strength of the fault zone and allows displacement along the fault (see Section Results) and the stiffness difference between the fault gouge and the rock mass (Steindorfer, 1998). One of the consequences of this phenomenon is that the effects of the far side excavation are mostly eliminated by the fault zone. Consequently the tunnel face cannot support the excavation, resulting in extremely high deformation in front of the tunnel face, and low deformations on the near side after the tunnel face advances (Kovács et al. 2009b).

**TESTING**

During the excavation of the underground facilities, face mapping was performed, and the Q (Barton, 2002), RMR (Bieniawski, 1989) and GSI (Hoek, 1994) values were determined. Systematic rock sampling and laboratory tests were carried out during construction to determine the properties of intact rock. The systematic sampling was in accordance with the relevant ISRM recommendations and the MSZ-EN

Opposite, top: Figure 3, Modelled displacement of the liner near the fault zone

Below: Figure 2, Geometry of the FLAC 3D model (red: fault zone, green: less competent rock mass near the fault zone, blue: typical rock mass near the modelled area)

FLAC3D 5.00  
©2012 Itasca Consulting Group, Inc.

Shell  
Plane: on front back  
Colorby: ID  
100  
101

Zone  
Plane: on  
Colorby: Property young  
1.500e+05  
3.382e+06  
4.044e+06  
4.901e+06  
6.205e+06  
7.712e+06  
9.597e+06

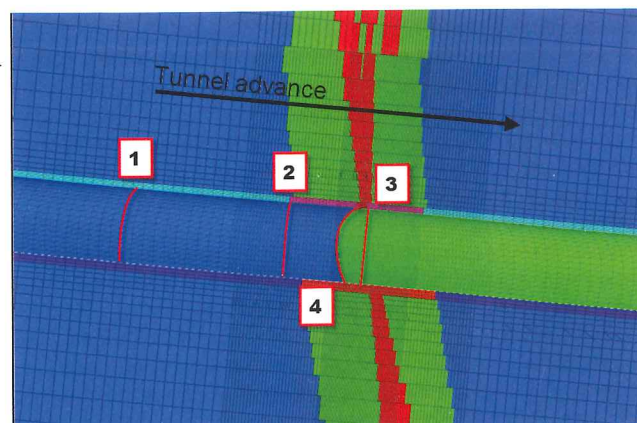
codes. Traditional triaxial tests with various confinement stresses (0 -15MPa) as well as Multiple Failure State Tests were carried out to determine the Hoek-Brown parameters (Vásárhelyi et al., 2013). The shear strength of the joints had been measured by laboratory tests (Buocz et al., 2010) and had been verified by distinct element models (Horváth, 2011 and Borbély, 2013). Two-dimensional Doorstopper-cell and 3D CSIRO HI-cell measurements were carried out to determine the in-situ stresses. These are widely used overcoring techniques. According to field measurements KO varies between 1.34 and 1.5. CSIRO HI cells are also used for measuring the stress changes of rock wall caused by the tunnelling.

In the underground facilities at the NRWR convergence measurement arrays were installed in 19 sections so far, two of them were measured in test drift. In these sections relative displacement of the rock mass surrounding the excavation has been measured repeatedly in six radial directions that enclose an angle of 30° with each other. Thirteen borehole extensometer sections and two Modular Reverse Head extensometers are also installed for measuring the radial and axial displacements of rocks around the tunnels including the entire Longitudinal Displacements Profile (LDP). The capacities of 10 per cent of the rock bolts were tested at the NRWR Project. In case of some tests the displacements were measured, thus the grouting properties were determined. Automatic measuring sections are installed for controlling the loads acting on the supporting elements.

**NUMERICAL MODELLING**

To gain better understanding of the rock mass behaviour around the test drift driven through Peter-fault zone, 3D finite difference modelling was carried out using Itasca FLAC3D (model geometry shown in Figure 2). Using 3D instead of 2D modelling allowed for the following:

- Major horizontal in situ stresses are not parallel or



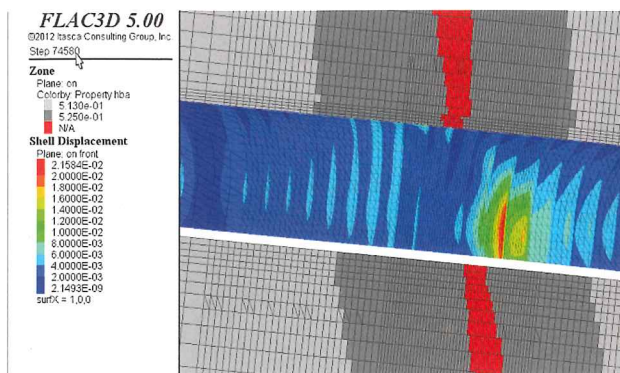
- perpendicular to the tunnel axis;
- Tunnel advance was modelled step by step; and
- Fault zone was not perpendicular to the tunnel.

As Figure 3 shows, the fault gouge is directly considered in the model (shown in red). The fault zone is accompanied by a highly fractured rock mass, found between the fault zone and the fairly good quality rock mass.

Each excavation sequence was modelled separately using the following steps: Excavate rock, install liner and rock bolts, increase concrete age by one cycle time – set time-dependent concrete properties.

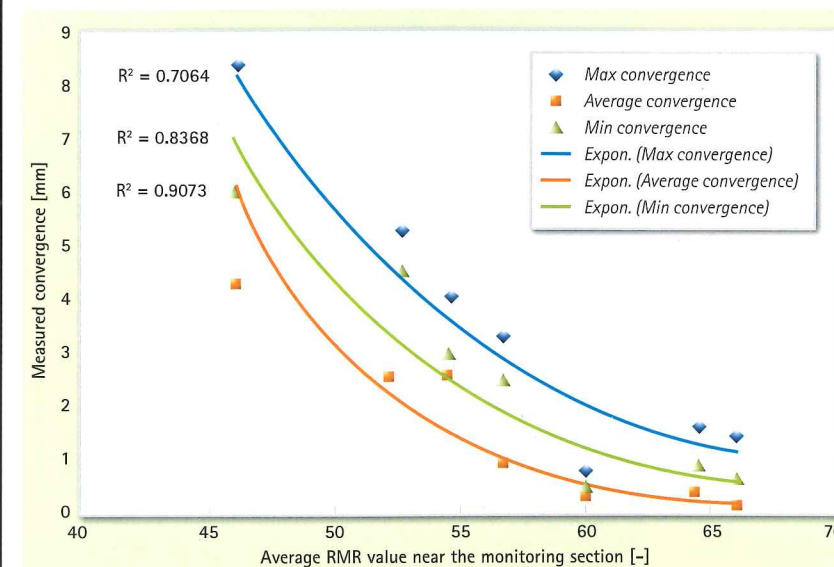
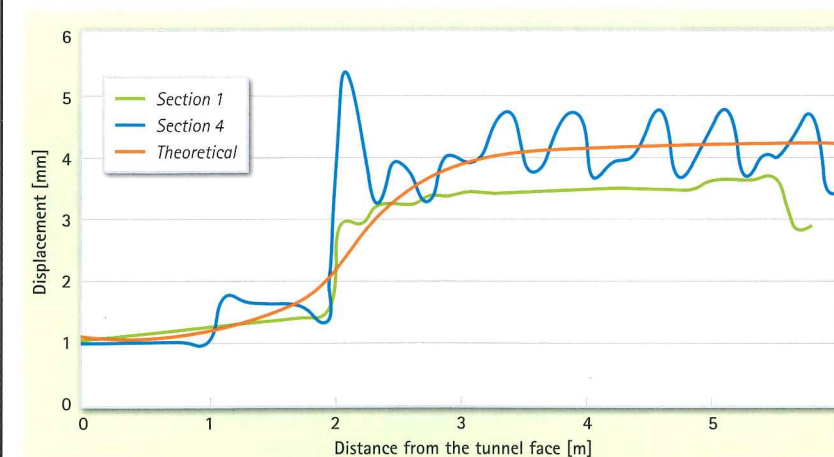
The Hoek-Brown failure criterion and Geological Strength Index (GSI) system was chosen for describing the rock mass as it provides a practical means to estimate rock mass strength from a combination of laboratory test values and field observations (Hoek, 1994). Intact rock properties were determined separately for monzogranite and monzonite. The GSI value of the rock mass is determined during tunnel excavation through continuous face mapping. The encountered rock mass is categorized into one of the five pre-defined rock classes (rock class I to V). The rock mass properties along the tunnel axis were represented using rock classes III and V, based on exploratory drilling data (blue and green zones in Figure 3, respectively).

The steel fibre reinforced sprayed concrete lining is modelled with the built in shell elements of FLAC3D. In the case of sprayed concrete lined tunnels, the lining is subjected to loads long before



Below: Figure 4, Modelled and theoretical longitudinal displacement profile

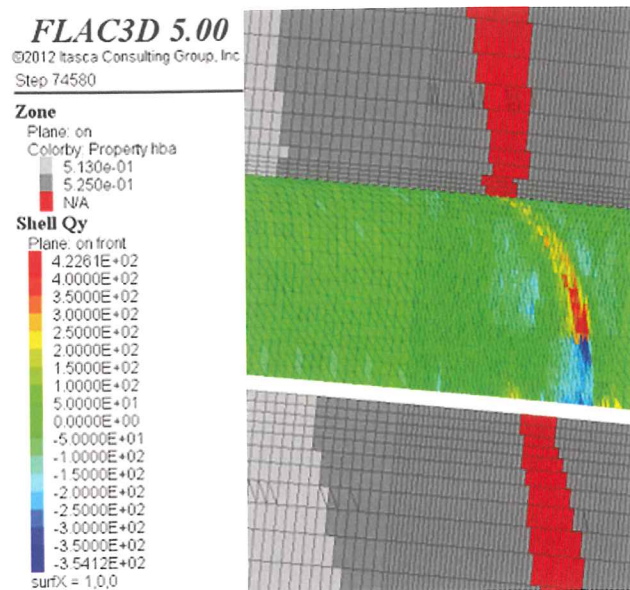
Bottom: Figure 5, Site specific relation of RMR value and convergence



it reaches its final strength and stiffness (in fact the concrete lining is usually loaded a few hours after the installation). The early age properties of the concrete were determined according to Chang and Stille (1993). The support provided by the rock bolts is taken into account with global reinforcement element (cable element). The rock bolt properties applied in the model are summarized in Table 2.

**RESULTS**

Displacements are reliable indicators of the model behaviour; therefore they can be used to verify the model by comparing to actual measurements. Displacements were extracted from the model in two sections. The first is sufficiently far from the fault zone, where the fault does not influence displacements. In this section the displacement was compared to the site specific RMR-displacement function, which is based on seven convergence monitoring sections in rock masses with a RMR value from 45-65. The modelled displacements were 5.9-9.7mm, while the actual measured displacements were 5.5-9.9mm (in case of sections with similar RMR value). As such, the displacement in the model shows very good agreement with the monitoring result. The second control section was in the middle of the fault zone. The modelled displacements in this area were 40cm (Figure 3). No measurements were carried out in the fault zone due to the difficulties of the crossing; however the construction logs indicate that the tunnel section needed to be re-scaled a few times before the sprayed concrete was installed due to the high displacements. The high (>10cm) displacements were limited to the approximately 0.5m thick fault zone. Based on this observation, the modelled displacement is considered to be reasonable. According to the model and field observation, the clay gouge is in plastic state. This indicates that the stress redistribution is governed by both the low strength of fault gouge and the stiffness difference between the rock mass and the fault gouge.



Above: Figure 6, Observed crack and high internal forces in the model

The longitudinal displacement profile (LDP) was also extracted from the model (Figure 4). A LDP relates tunnel wall deformations at successive stages to the physical location along the tunnel axis (i.e. the distance from the tunnel face). The observed LDP in the model is uncommon to rock tunnels. Near the fault zone, almost all displacements occur close to the tunnel face. Further away from the fault zone, the LDP in the model is close to the theoretical profile corresponding to circular tunnels in homogenous rock mass (Vlachopoulos and Diederichs, 2009). At Section 1, the effect of the fault is less significant, so the difference between the theoretical and modelled profile is minimal.

The LDP was not measured near the fault zone, however relaxation was measured in the HGM chamber where a minor fault zone was penetrated. In Kon-6 section (installed 1-2m before the fault zone) the measured convergence is significantly less than what is calculated

by using the RMR value for the rock mass (Figure 5). This is potentially caused by high relaxation near the fault zone.

According to the model, high stresses and internal forces occurred in the liner. Both bending moments and shear forces were above the capacity of the lining. This result is in good agreement with the construction experience as it was observed that the liner cracked. The peak stresses in the lining coincide with the crack location and orientation, indicating that the internal forces in the tunnel lining are modelled with a good agreement with the reality (Figure 6).

The general model behaviour is considered to be in close agreement with the actual rock behaviour and can be used to facilitate understanding the observed behaviour. To demonstrate the stress reflection effect, the stress redistribution during tunnel drive was considered (Figure 7). One can see that the stress does not change on the far side of the fault zone before the fault zone is penetrated. In contrast, high stress concentration can be observed between the fault zone and the tunnel face. This finding is in agreement with the results presented in Grossauer et al (2005): tunnelling through a rock mass with frequently changing stiffness at short distances, stresses will concentrate in the "stiff" sections. The stress redistribution on the far side of the fault zone takes place only after the fault zone is penetrated.

### SUMMARY AND CONCLUSION

Detailed analysis of a fault zone was presented here in order to gain better understanding of the effects associated with tunnelling through thin fault zones. One of the most important findings of the paper is the confirmation of the stress reflection concept. It has been shown that the rock mass on the near side of the thin fault zone is fully or almost fully relaxed (all displacements occur) before the tunnel lining is installed; while the rock mass on the far side of the fault zone is not relaxed at all (has in-situ stress conditions and negligible displacements). Based on the results, it is recommended that the rock support is designed to be able to handle stress and strains from the full overburden pressure on the far side, or at least be flexible enough to allow relaxation of stress after the rock support installation (Figure 3). Typically fast tunnel advance can be helpful, due to the early age creep of the concrete.

Most of the stress redistribution occurs before or at the same time as the rock support is installed on the near side of the fault crossing. Immediate support is recommended to provide support and avoid overbreak. Lattice girders were a good and reasonably simple solution. They provided immediate support to some extent while allowing movements on the other side of the fault. It is recommended not to rely on the longitudinal load-bearing capacity of the tunnel lining once the fault zone is penetrated.

The displacement after lining installation is significantly different on the two sides of the fault zone, therefore significant shearing and bending is expected. As it was pointed out earlier, a crack formed due to this effect. The crack did not pose a risk in the presented example as the tunnel is drained and the liner does not have any water insulation function, however, a developing crack might cause difficulties in case of a gasketed segmental tunnel lining design. The stress reflection effect can be modelled using 2D modelling for design purposes. Two separate models are needed to consider the near side and the far side of the fault zone. On the near side it is a reasonable estimation to use 90 per cent -100 per cent relaxation, i.e., the majority of the rock mass movements occur prior to tunnel installation. To model the far side of the fault 0 per cent-10 per cent can be used. Hence the suggested support method allows some movement on the far side of the fault zone, and provides immediate support on the near side. The adequacy of the designed tunnel support can be verified with simple 2D numerical modelling, while the three-dimensional

### References

Balla, Z., 2004. General characteristics of the Bataapati (Uveguta) Site (South-western Hungary). In: Annual Report of the Geological Institute of Hungary, pp. 73-85.

Barton, N., 2002. Some new Q-value correlations to assist in site characterisation and tunnel design. International journal of rock mechanics and mining sciences, 39(2), 185-216.

Benkovics, I. et al. 2010. National Radioactive Waste Repository Emplacement Chambers, Construction Design, 2.3 stage (in Hungarian) Bieniawski, Z., 1989. Engineering Rock Mass Classifications. New York: John Wiley & Sons.

Borbély, D., 2013. Three-dimensional distinct element modelling of a drill and blast tunnel in crystalline rock. Proceedings of the 5th International Young Geotechnical Engineers 337-340 edited by Cui YJ.

Buocz, I., Rozgonyi-Boissinot, N., Görög, P. & Török, Á., 2010. Laboratory determination of direct shear strength of granitoid rocks; examples from the host rock of the nuclear waste storage facility of Bataapati (Hungary). CENTRAL EUROPEAN GEOLOGY, pp. 405-417.

CEDD 2015 Civil Engineering and Development Department Catalogue of Notable Tunnel Failures - Case Histories (up to April 2015) Prepared by Mainland East Division Geotechnical Engineering Office Civil Engineering and Development Department [Online] <http://www.cedd.gov.hk/eng/publications/geo/doc/HK%20NotableTunnel%20Cat.pdf>

Chang, Y., and Stille, H. 1993 Influence of early-age properties of shotcrete on tunnel construction sequences, Shotcrete for Underground Support VI., 110-117

Grossauer, K., Schubert, W., and Sellner, P. 2005. The importance of displacement prediction. Underground Space Use-Analysis of the Past and Lessons for the Future: 1239-1244.

Hoek, E. 1994. Strength of rock and rock masses, ISRM News Journal, 2(2), 4-16.

Hoek, E., 1994. Strength of rock and rock masses. ISRM News Journal, 2(2), 4-16.

Horváth, Z., Megyeri, T., Váró, Á. and Görög, P., 2012. Discrete element modelling of the Mórógy Granite Formation Southern Hungary. 1st Eastern European tunnelling Conference pp22 edited by Horváth T.

Kovács et al. 2012 Geotechnical investigation report. RHK-K-032/12

Kovács, B., Bothi, Z., Molnár, P. & Gy, D., 2010. Development of final disposal concept for NRWR (in Hungarian). RHK-K-093/09

Kovács, L., Molnár, P. and Szebényi, G. 2009b Summary report of instrumentation and monitoring in HGM chamber (in Hungarian) RHK-K-053/09

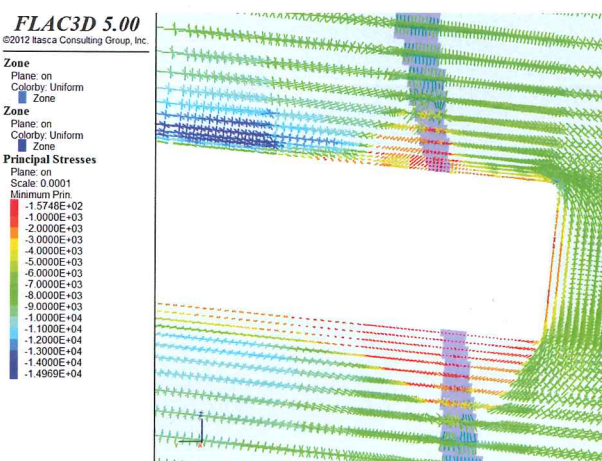
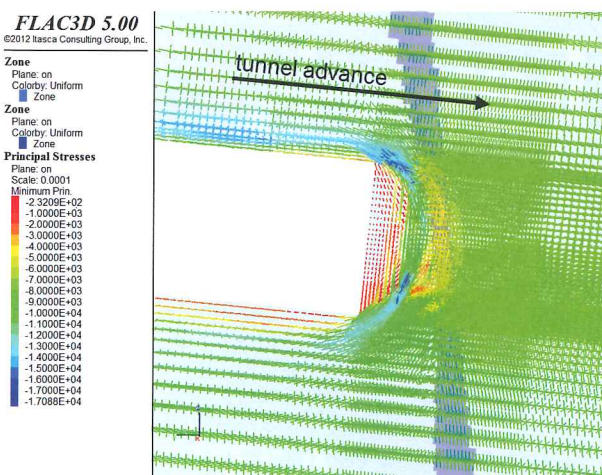
Megyeri, T. et al., 2014. Conceptual design of full scale final sealing test in 3rd test chamber RHK-K-007/14

Steindorfer, A.F. 1998. Short term Prediction of Rock Mass Behaviour in Tunnelling by advanced Analysis of Displacement Monitoring Data. PhD thesis, Graz University of Technology, Austria.

Vásárhelyi, B., Kovács, L., Kovács, B. 2013. Determining the failure envelope of the intact granitic rocks from Bataapati. Geosciences and Engineering, 2(4), 93-101.

Vlachopoulos, N., Diederichs, M.S. 2009 Improved Longitudinal Displacement Profiles for Convergence Confinement Analysis of Deep Tunnels. Rock Mech. and Rock Eng. April 2009, 42(2) 131-146

WNA, 2014 - september. Information Library: Nuclear Wastes. [Online] <http://www.world-nuclear.org/info/nuclear-fuel-cycle/nuclear-wastes>



Left: Figure 7, Modelled stress redistribution near the tunnel face

The authors want to express our gratitude to RHK Ltd. and Mecsekérc Ltd. for granting us permission to collect and use data related to the NRWR project. Our gratitude is extended to Connor Langford for his useful suggestion to the early version of the paper

effect of a fault zone is considered. If high overbreak, raveling or squeezing of the rock mass is expected (which was not the case in NRWR project) spiling and forepoling can be used to prevent overbreak on the near side of the fault zone. Spiling or forepoling can provide support, and bridge the fault zone to reduce the stress reflection effect (as it was stated earlier the longitudinal elements are subjected to high loads once the fault zone is penetrated).

This study was carried out during the detailed design of the side drift excavation where the full scale test is to take place. Since then, the side drift has been successfully excavated. It is of interest to note that the fault zone has been found to be significantly different from the prognosis on which this study is based. As described above, the fault gouge mainly responds to mechanical stresses with plastic deformations at the location where the two inclined access tunnels penetrated it. However, at the location of the future full scale test (the side drift) the fault zone is significantly thicker and exhibits blocky behaviour as it is mainly composed of the fault breccia, and clay is only to be found in its discontinuities. Further studies will be carried out to back-analyse the side drift excavation in a similar manner as this paper and to summarise the experience of crossing the thicker fault zone

# Tunnels

AND TUNNELLING

The leading tunnelling magazine for 47 years!

**SUBSCRIBE TODAY** to receive  
twelve print + digital issues with a  
**SPECIAL 10% DISCOUNT**

**To Subscribe:**

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

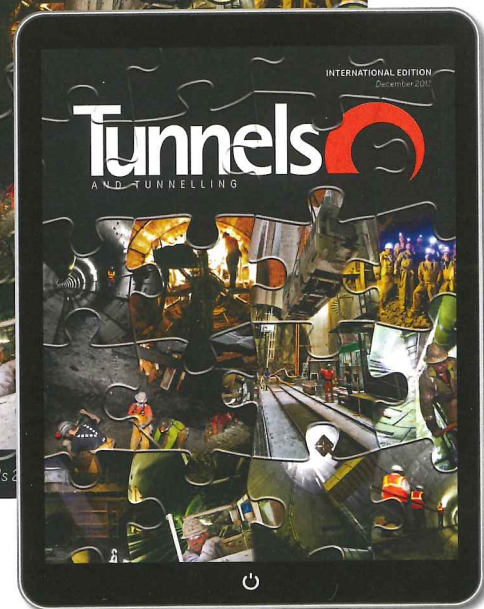
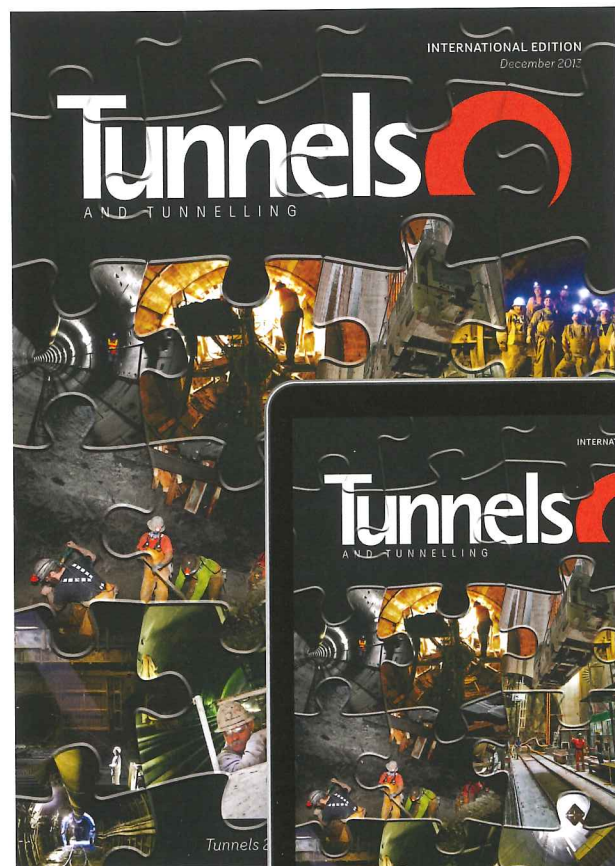
**Call:** +44 (0)845 073 9607

**Email:** [cs@progressivemediagroup.com](mailto:cs@progressivemediagroup.com)

**Fax:** +44 (0)207 458 4032

**Visit:** [www.tunnelsonline.info](http://www.tunnelsonline.info)

Quoting TUNHAD



# TUNNEL WARFARE

**W**AR, ALTHOUGH INHERENTLY FRIGHTFUL with its carnage and bloody reality portrayed almost daily on our TV screens, still has a compelling fascination for many, particularly men, with its tales of daring, gallantry, heroism and self-sacrifice. This nostalgia seems to be heightened when tunnelling and underground activities are involved with the added claustrophobia this entails. Not only is the military miner excavating a tunnel faced with the inherent dangers this task normally involves but in wartime he faces the persistent apprehension of knowing that the enemy is working assiduously either to blow him up or cause a collapse to bury him alive or trap him underground to die a lingering death. Such heightened tensions serve to make the story of the British tunnellers on the Western Front during the First World War more compelling. »

Former *Tunnels and Tunnelling* Editorial Advisory Board chairman **Myles O'Reilly** gives this compelling account of some historical techniques and cases of tunnelling used to conduct war. This is the first of a two-part article



While causing great damage to both soldier and battlefield, conventional shelling had minimal impact on fortifications



Gift subscriptions & back issues available online

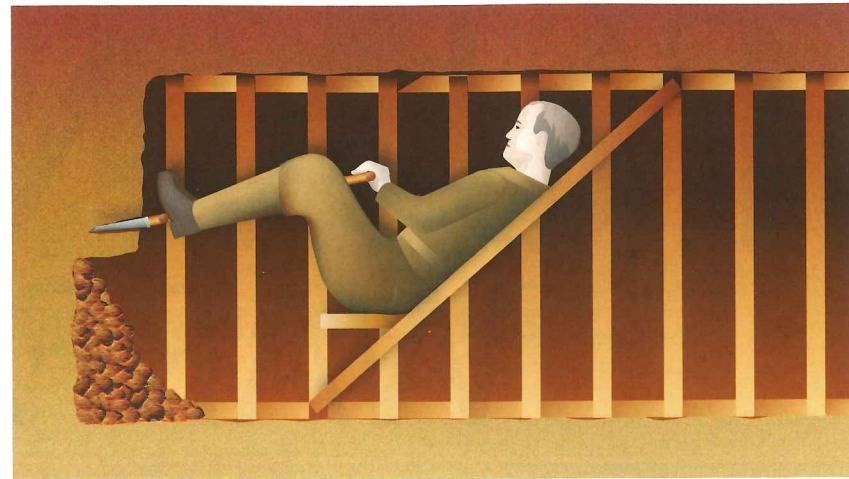
[www.tunnelsonline.info](http://www.tunnelsonline.info)

**HISTORICAL BACKGROUND**

Underground warfare began at sieges where undermining, the process of gradually extracting the ground supporting the foundations of fortress walls through a tunnel driven beneath them, was used. The Egyptian Army were already using such techniques to subdue strongholds under siege some four millennia ago; by 850 BC the Assyrians had a special corps of military miners dedicated to that purpose.

In a siege once one or more critical points in the defensive walls had been identified tunnelling, if feasible, could begin where possible at a point out of sight of the defenders and beyond the range of their missiles. Such tunnels were rarely more than a few metres deep; solid rock and moats were considerable obstacles to their use. When the target was reached the end of the tunnel was enlarged to form a chamber supported with timber props beneath the foundation; the props were then set alight to cause a collapse and result in a breach in the wall above. Less often the tunnel would penetrate into the interior of the walled city and allow the attackers to emerge and surprise the defenders.

Apart from adverse ground conditions and deep wide moats the success of a mine attack depended on the response, if any, of the besieged. If they became aware of offensive tunnelling the defenders could drive their own tunnels – counter mining – to intercept their attackers and engage them in hand-to-hand fighting underground. Other defensive ploys included flooding or smoking out the hostile galleries or the



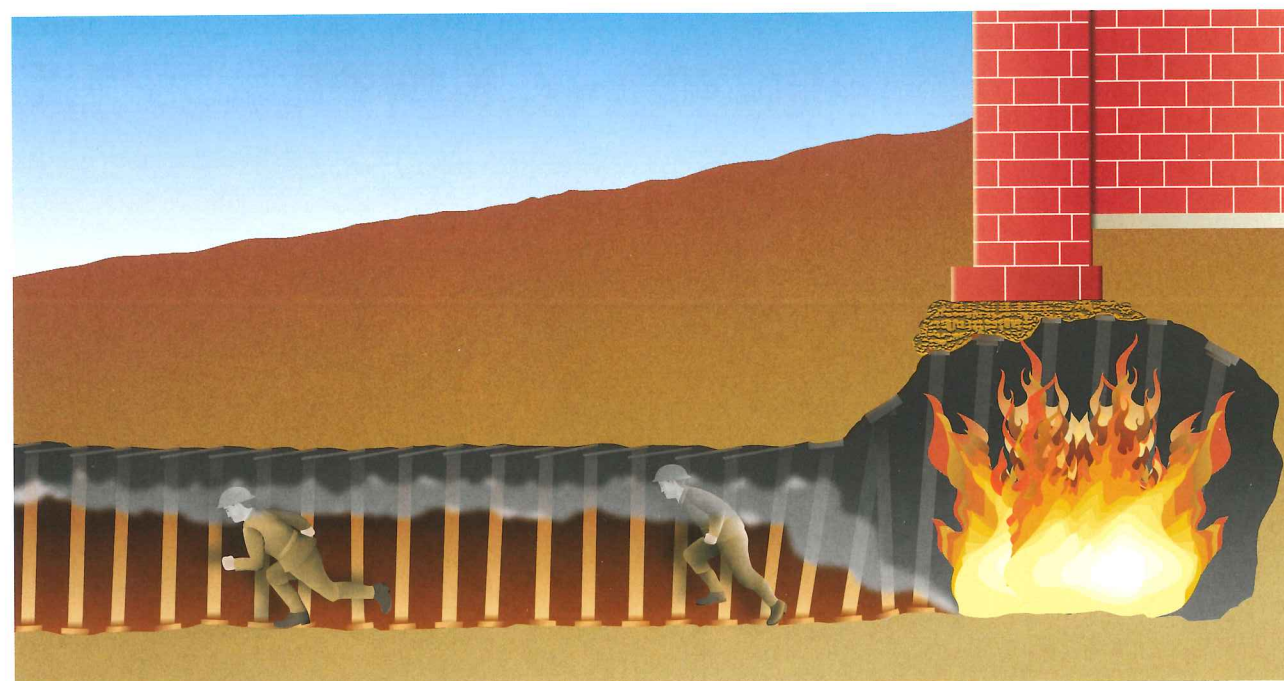
*Above: Clay kicking, a tunnelling technique unique to the northwest of England found application in the trenches*

*Below: Undermining an enemy fortification by setting fire to temporary supports*

introduction of angry bees or ferocious animals into them.

In Europe gunpowder began to add a new dimension to mine warfare from the 15th Century. It enhanced the besiegers ability to destroy fortifications but also enabled the besieged to wipe out attacking tunnels with an explosion of limited extent called a camouflet without causing a crater at the ground surface. The 16th and 17th Centuries saw the replacement of castles and defensive walls by squat, more resilient structures due to improved artillery. But counteracting mining was still difficult and by the end of that period permanent systems of countermines spreading outwards from within fortresses to well beyond their defenses and ditches were quite common; however large his force of tunnellers the besieger would be compelled to engage in a lengthy underground conflict. Although this increase of military mining did not initially result in the formation of specialist units in armies by the end of the Napoleonic Wars, both France and Great Britain had specialist mining groups within their forces.

As protracted sieges became less frequent, several episodes showed that there was no reduction in the value of mining as the 19th Century progressed. In India mining was used at the sieges of Bhurtpore (1825-1826) and Lucknow in 1857, in the Crimean War at the siege of Sevastopol in 1855 and beneath



*Above: Concrete fortification destroyed by a tunnelled explosives cache. Such structures could be several metres underground*

Confederate trenches at the siege of Petersburg, Virginia, in 1864 during the American Civil War. In the Russo-Japanese War of 1904-1905 mining by the attacking Japanese proved decisive at Port Arthur where it was again deployed against trenches.

This brings us to the 1914- 918 First World War and the mining and countermining on the Western Front and reaching a climax in the big bang at the Messines Ridge in 1917.

**THE CONFLICT BEGINS**

Following the rapid German advances through Belgium and into France in August 1914 the allies, Belgium, France and Great Britain, stabilised the situation in September and four years of static trench warfare ensued along the Western Front, which extended from the North Sea coast to the Swiss border. Below ground the Germans took the initiative in the British Sector; their opening move was on 20 December 1914 at Le Plantin, northern France, with the simultaneous detonation of 10 small mines beneath trenches manned by the Indian Sirhind Brigade. Again, on 25 January 1915, some 20 small charges at Cuinchy, also near La Bassee, caused heavy casualties. A significant length of frontline trench was lost and despite counter attacks by the Guards the Brigade was not recaptured. Once more on 3 February soldiers of the East Yorkshire Regiment were mined from their trenches near the village of St Eloi.

Although John Norton-Griffiths, proprietor of Griffiths & Co, a civil engineering contracting firm, and conservative MP for Wednesbury, had written to the War Office in mid-December 1914 offering to assemble a company of 'moles' it was not until 12 February 1915 that the secretary of state for war, Lord Kitchener, met with him. Initially Norton-Griffiths' letter had been filed and the proposal treated with scepticism - how could undisciplined construction workers be given one of the most

onerous tasks in warfare? But needs must be met in desperate times and the upshot of the meeting was to get things really moving. Formal approval for the formation of nine tunnelling companies, each of five offices and 269 men, was given a week later.

**THE TUNNELLING COMPANIES**

Norton-Griffiths was a charismatic and charming individual with boundless energy and enthusiasm. Appointed a major in the Royal Engineers (RE), he was given a free hand in the development of the new tunnelling companies. A quick visit to the front had assured him that a tunnelling technique known as 'clay kicking' would be suitable for driving tunnels in the clay soils in Flanders. Clay kicking was unique to the north west of England and had been used in the construction of sewers in Manchester, Liverpool and Preston. It was a technique used to drive a tunnel so small that the miner had insufficient room to swing a pick. The miner, supported by a substantial wooden cross set up at an angle of about 45 degrees, used a small sharp spade known as a grafting tool to stab into the clay; he then drove the tool home with his legs, and prised the clay down in chunks. Once the initial

opening had been made, usually from the lower half of the face, progress was easier. The method was much quicker and more select and progress of about 8m per day was normal – considerably ahead of the enemy.

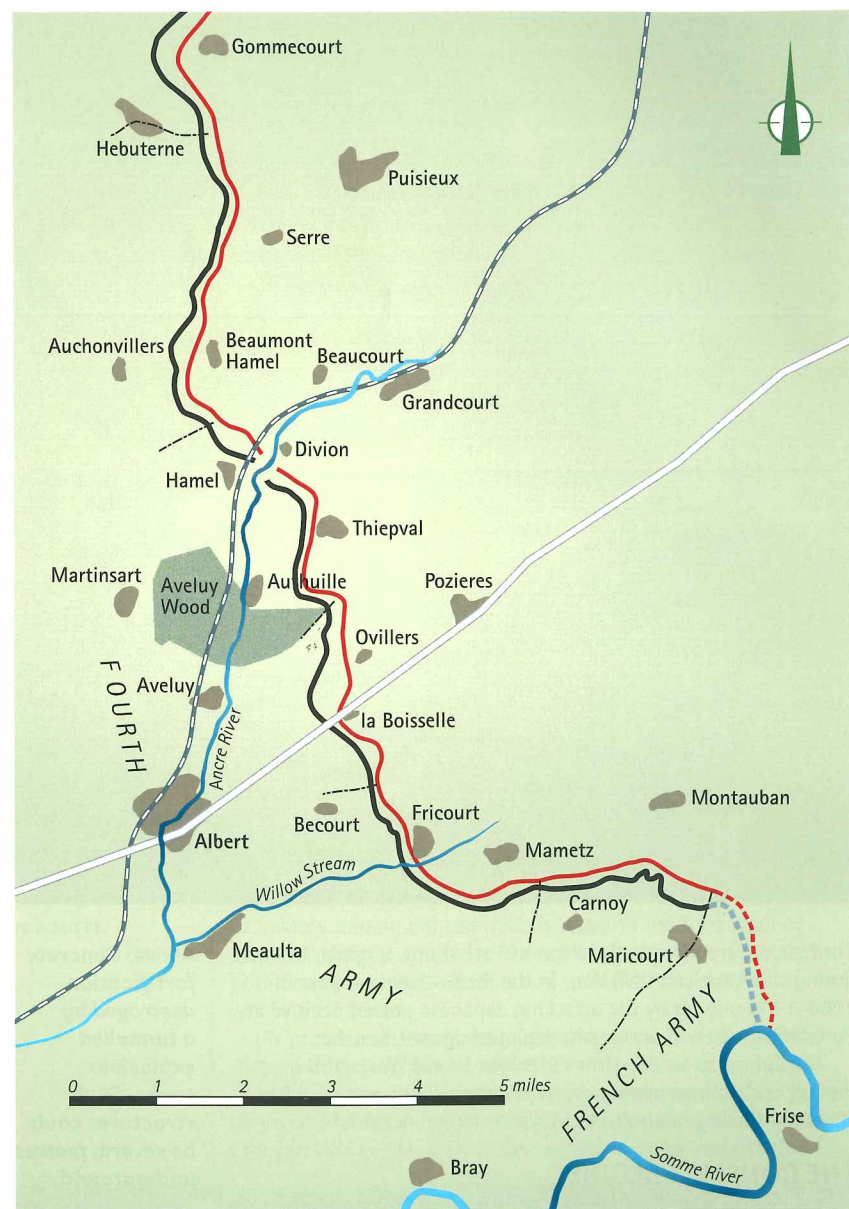
The first batch of 20 tunnellers arrived at the Tunnelling Depot, Westminster, London, on 18 February 1915 and were dispatched to RE headquarters at Chatham; all were from Norton-Griffiths' sewer contract in Manchester. Eighteen were passed fit on medical examination and were in uniform that Thursday, in Dover on Friday, France on Saturday and digging tunnels near La Basse on Sunday as part of the 170th Tunnelling Company; none had received any military training. At Chatham a batch of 66-36 coal miners and 30 clay kickers – were equipped and on their way to France on 22 February 1915; divided into two equal groups, one headed to join the clay kickers in Bethune, while the other group went by lorry to Ypres, now Ieper; they were allotted to the front line opposite the notorious Hill 60. A few days later, on the 27 February, 80 miner volunteers and two officers from the Monmouthshire Regiment joined and the 171st Tunnelling Company (TC) had been formed.

Enlisting tunnellers were assessed at Chatham. Face men who did the digging and tunnelling were of prime importance and were paid six shillings and sixpence a day. A secondary group assisted them and were responsible for bagging the spoil and removing it from the tunnel; they received two shillings and two pence per day. By comparison the daily pay of the average infantryman was one shilling and three pence. A third group were there who had been foremen in civvy street and normally became NCOs, a sprinkling of regular warrant officers from the regular army to provide some military experience.

A tunnelling company was commanded by a regular RE major or captain with four section officers with the temporary rank of subaltern. Most of the latter arrived without military experience having received only a single week's instruction at Chatham; but there were some engineers often from the Commonwealth with mining experience or relevant professional and academic qualifications.

### HILL 60 ERUPTS

A little over 3km from Ypres, Hill 60 was located beside the single track railway, that ran south-eastwards to the Franco-Belgian border, where it passed through a cutting in the Messines Ridge. Surplus excavated material from the cutting had



Above: Map of the Somme Valley during the conflict

been dumped in three heaps, the largest of which peaked at an elevation of 60m, hence its name Hill 60. The others, the Caterpillar and the Dump, were to the south on the opposite side of the tracks. Like most of the Messines Ridge all three were in German hands at the beginning of 1915 and here as elsewhere in the Ypres Salient, they overlooked the British frontline.

The British were not happy with this situation although it was recognised that the German defences on the ridge were exceptionally strong. However, mining was a distinct possibility and orders were issued for tunnelling to Hill 60 and the village of St Eloi some 3km further south. Initially the equipment supplied was antiquated having lain in store since the Crimean War of 1853-56. In particular the air pumps were very noisy when operating in a situation where silence was essential if the enemy was not to be alerted and retaliate by exploding a camouflet nearby.

Although difficulties were experienced in locating and sinking the shafts near Hill 60 by 8 March 1915, three starting positions – M1, M2 and M3 – had been agreed and excavation began often in the upper layers through the decomposing bodies of dead soldiers.



Above: Positioned below the lip of the trench, soldiers are protected from blast shockwaves and shrapnel

When the shafts reached a depth of 5m tunnelling towards the German lines commenced. Tunnels were 0.7m wide and as little as 0.9m or so high and had to be timbered in the wet sandy clay; working in shifts they advanced about 3m per day.

Some days later disaster struck at St Eloi. A German attack preceded by a barrage and the detonation of three mines beneath their trenches had driven the British from the village. It was another mining success for the enemy who were clearly ahead in the underground conflict. At Hill 60 daily rates of progress increased to over 4m as the miners dug with increasing ferocity to win the race to place and detonate their charges. Tunnels M1 and M2 went straight into no-man's land for about 90m then branched to form two charge chambers beneath the German trenches. Excavation in them finished on 10 April and charging began. At this stage the chambers at the end of the M3 tunnel had already been loaded with two 500lb (227kg) charges of guncotton. Pairs of charges of 2,700lb (1,225kg) and 2,000lb (907kg) of gunpowder were required at M1 and M2 respectively to create craters about 18m in diameter; as gunpowder was supplied in 100lb (45kg) bags this involved the manhandling of 94 such bags into position.

All were in place, fused and ready by 15 April. The British attack began on 17 April and the mines were detonated as planned. As the debris from the explosions were still spiralling back to the ground, three British artillery brigades and two batteries with Belgium and French guns in support opened up and the infantry charged towards the Hill and captured it.

The craters were all larger than expected and 171 TC had won the day.

However, the success was short lived. The breakthrough had been deep and narrow exposing the British to fire from two sides. They were still fighting three days later but despite heavy losses they still held on. But all the bravery was to no avail in the end. On the 5 May 1915 a whirling green mist of chlorine gas began to envelop the hill and its defenders who did not have gas masks were forced to retreat leaving the Germans once again in occupation.

### TIT FOR TAT MINING

Other than the events at Hill 60 just described no great

attempt was made to coordinate mining operations during 1915. The soldiers in the trenches preferred defensive mining operations where the enemy was active underground and to let sleeping dogs lie where he was not.

But mining still continued although more limited in scope and objectives. At St Eloi some 4km south of Ypres a small ancient tumulus known as 'The Mound', which overlooked the British trenches was targeted by 172 TC. Starting in April an array of listening posts was developed in shallow tunnels so that the British trenches could be protected with camouflets and followed up with a number of deeper attacking mines. By the end of June seven camouflets had been blown and five mines had been placed beneath German trenches and 'the Mound'. The mines detonated at intervals on the morning of 10 July 1915 saw the Germans flee their frontline trenches. Unfortunately artillery support could not be provided due to the shortage of shells and the counterattacking Germans soon regained the lost ground.

At Hooze, a village about 3km east of Ypres, 175 TC started mining in June 1915. After an unsuccessful attempt to sink a shaft through water logged sandy ground a second shaft was sunk into clay at a depth of about 11m. A tunnel 58m in length initially 2.13m high by 0.75m wide and reduced to 1.2m high as it approached beneath the pair of targeted redoubts was driven through the clay with close timbering. A charge of 4,200lb (1,905kg) of ammonal together with smaller amounts of gunpowder and guncotton were placed and tamped with several tons of bagged clay and sand. Detonated at 7pm on 19 July 1915, it created a crater about 36m in diameter and killed between 200 and 600 Germans. The whole village was now in British hands. The triumph was again short-lived and by the end of the month the Germans had regained all and more of the lost ground. It was obvious by now that attacking mines could not take and hold enemy positions alone but were of considerable value when used as a shock tactic at the beginning of an attack.

Meanwhile, much was happening to the south where British forces were replacing French as far as the River Somme. The Germans availed of the opportunities provided by the changeover to push ahead underground. Unlike the soft ground further to the north the ground here was chalk overlaid by sedimentary soils, clay with flints, loess, loam and alluvium; it was easier to excavate and required little timbering until shattered by repeated explosions.



On the other hand mining activity was unavoidably noisy, the risk from carbon monoxide gas given off by explosions was much increased and it was difficult to camouflage the brilliantly white excavated material. For example when the British took over at Tambour they inherited a system of galleries 1.5m high by 0.9m wide some 4m in front of their trenches driven in the chalk and accessed by shafts about 10m deep. Smaller fighting galleries poked out towards the enemy to be used as listening posts and to charge and fire camouflets when a German approach was detected. The enemy was doing much the same and several German headings had been pushed forward during the takeover period and had to be repulsed. A nerve wrecking game of blind man's buff ensued as the rival miners sought to outsmart each other. Many miners were killed underground mostly by camouflets either crushed by collapse of their tunnel or trapped in a pocket of carbon monoxide.

As time passed, deeper tunnels were driven at depths from about 21 to 31m down and so the gruesome routine of probe and counter attack continued to the end of 1915 and into 1916.

**THE BATTLE OF THE SOMME**  
The aim of this British offensive

**Above: Well-defended trench lines were a challenge for conventional artillery**

commencing on 1 July 1916 was to relieve pressure on the French forces defending Verdun in the south. It opened with the firing with seven large and 11 small mines along a 29km front stretching from Maricourt near the River Somme in the south to Gommecourt in the north.

In April just 10 weeks before the attack each of the five TCs involved received their instructions for attacking mines and for galleries to provide advanced emplacements for machine guns and mortars; they were also expected to maintain their defensive systems.

These requirements put great pressure on resources but the response of the miners was excellent. For example, one tunnel 1.2m high by 0.7m wide was driven 183m in 28 days including 61m in a single week. The 40,000lb (18,144kg) of ammonal in the mines beneath the redoubt at Beaumont Hamel was excavated in dry chalk at a depth of 20m; it was fired at 0720hrs on the 1 July some 10 minutes before zero hours and resulted in a crater 20m deep and 55m wide.

Near La Boisselle the mine known as Y'Sap with the same weight of charge fired a minute before zero hour produced a similar effect. Less than 1km to the south Lochnagar consisting of twin charges of 36,000 and 24,000lbs (16,330 and 10,586kg) of ammonal placed about 20m apart resulted in a crater some 22m deep and 80m wide; it had destroyed mine dugouts killing hundreds.

But the attack that followed did not go at all well and by the end of the first day the British had lost 57,470 men either killed, wounded or missing. The campaign was scaled down and ended with the onset of winter weather in November.

By then British casualties had increased to 410,000 while the French of a shorter front south of the River Somme had lost 190,000 men. For this, just a paltry hundred square kilometers had been captured

ANCHORS

High Performance.  
Ultra Strong.  
British Designed.

www.excaliburscrewbolts.com

**Excalibur**  
SCREWBOLTS

T +44 (0)1702 206 962 / 207 909

BORING EQUIPMENT

**TERRATEC**

www.terratec.co

CHEMICALS

**WEBAC**<sup>®</sup>

consolidation-line.com

CONTRACTORS

**Thrust Boring Specialists**  
In Service Since 1983

www.anabeeb.com info@anabeeb.com +966 13 362 0556  
P.O. Box 234, Al Jubail 31951, Saudi Arabia

CUTTER TOOLS

**T.B.M. CUTTERS Ltd.**

DESIGN AND MANUFACTURE OF TBM CUTTING TOOLS AND WEARPARTS  
CUTTER HEADS MANUFACTURED & MODIFIED

TEL. +44 (0) 1430 427954 FAX. +44 (0) 1430 427955  
EMAIL. office@tbmcutters.com www.tbmcutters.com

CUTTER TOOLS

**PALMIERI** TUNNELLING - DRILLING

CUSTOM-MADE CUTTERHEADS FOR TBMs MICROTUNNELLING AND VERTICAL OR DIRECTIONAL DRILLING MACHINES.  
BACK UP AND MUCK HAULAGE SYSTEMS.  
ROLLING STOCK AND SPECIAL TUNNELLING RELATED EQUIPMENT

T: +39 0534 32511 F: +39 0534 32501  
E: info@palmierigroup.com W: www.palmierigroup.com

Agents wanted in selected countries. Please apply to: a.tasselli@palmierigroup.com

DIRECTIONAL DRILLING

**devico**

DIRECTIONAL CORE DRILLING & BOREHOLE SURVEYING INSTRUMENTS

Contact us devico@devico.no www.devico.com

DRILL and BLAST

**OSSA**  
OBRAS SUBTERRANEAS

1952 - 2012

Polígono Industrial Alcobendas.  
28108 Alcobendas (Madrid)  
T. +34 902 678 808 | F. +34 915 618 894  
www.ossaint.com

ENGINEERING CONSULTANTS

**Metroul**  
PROIECTARE ŞI CONSULTANŢĂ

T: +40-31-104.71.02  
metroul@metroul.ro  
www.metroul.ro

- Civil Engineering
- Environmental Engineering
- Transport Engineering
- Mechanical Engineering

ENGINEERING CONSULTANTS

**TONY RIDLEY HYPERBARIC ASSOCIATES LTD**  
Consultancy, Expertise and Personnel

**Specialist Tunnelling Services**

Compressed Air - TBM Intervention - Safety - Rescue - Occupational Health

Tel +44 (0) 1508 538 838 Fax +44 (0) 1508 538 938  
Email info@hyperbaric-tunnelling.com  
www.hyperbaric-tunnelling.com

**TYPESA**

www.typsa.com

Tunnels - Caverns  
Foundations - Slopes

**Consultants in Rock Engineering**

**GEO-DESIGN**  
www.geo-design.co.uk

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

ENGINEERING CONSULTANTS



**GEOCONTROL**  
BRASIL | CHILE | COLOMBIA | ESPAÑA | PERU

Tunnel Engineering  
Geological and Geotechnical Engineering  
Tunnel Safety Installations  
Rock Mechanics applied to Mining  
Technical Advice during Construction  
Site Supervision

Cristóbal Borja, Nº 19-21, 5º - 28003 Madrid (Spain)  
T: 34 91 553 17 63 | F: 34 91 554 93 96  
[geocontrol@geocontrol.es](mailto:geocontrol@geocontrol.es) | [www.geocontrol.es](http://www.geocontrol.es)

Specialists in Underground Works

EQUIPMENT



**METAX CIMA GROUP**

29122 Piacenza - Italy - Via Orsina, 33  
Tel. +39 0523 0103 Fax +39 0523 593106  
[www.metax.it](http://www.metax.it) - [info@metax.it](mailto:info@metax.it)

Jet Grout, Mud, Slurry Pumps  
Batching Plants - Injection Plants  
Drilling Rods - Ancillary Parts

**Sp SPECIALIST PLANT**  
TUNNELLING EQUIPMENT  
HIRE AND SUPPLY  
Tunnel Ventilation Systems  
UK Agents for **SVEBRA** LIGHTWEIGHT PIPING

Tel: +44 (0) 1234 781 882  
Email: [info@specialistplant.co.uk](mailto:info@specialistplant.co.uk)  
[www.specialistplant.co.uk](http://www.specialistplant.co.uk)

RAIL and ROLLING STOCK



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

for Mining, Tunnelling & Surface Transport

**Clayton Equipment Ltd**  
[www.claytonequipment.co.uk](http://www.claytonequipment.co.uk) Tel: +44 (0) 1283 524470

VENTILATION



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

Amflex Wire Reinforced and Layflat Tunnel Ducting

Spiral Duct  
Extraction Ducting Warm Air Ducting Ventilation Ducting Mining & Tunnelling

Tel +44 (0) 1709 872574 Fax +44 (0) 1709 879020  
[amcoplastics@naylor.co.uk](mailto:amcoplastics@naylor.co.uk) [www.naylor.co.uk](http://www.naylor.co.uk)

GROUND CONTROL



**hw hoelscher dewatering**

- dewatering
- groundwater control
- water treatment

[www.hw-dewatering.com](http://www.hw-dewatering.com)

INJECTION EQUIPMENT



**CK-Tech Ltd DESOI**

Official UK Distributor of DESOI  
Injection Pumps, Packers & Accessories.  
Underground Consultation & Training.  
[info@ck-tech.co.uk](mailto:info@ck-tech.co.uk)  
Tel: 0843 8863 998  
[www.ck-tech.co.uk](http://www.ck-tech.co.uk)

RAIL and ROLLING STOCK



**Maschinen Stahlbau Dresden**  
Branch of Herrenknecht AG

Jobsite logistics  
Shaft installations  
Customized back-up systems  
High-performance rolling stock  
[www.msd-dresden.de](http://www.msd-dresden.de)

**VALENTE**  
TUNNELLING EQUIPMENT  
ROLLING STOCK - TURNOUTS  
LOCOMOTIVES  
WAGGONS

Via Don Minzoni, 06 Phone: +390293799212  
20020 Lainate (MI) ITALY Fax: +390293799349  
[www.valente.it](http://www.valente.it) [info@valente.it](mailto:info@valente.it)

RECRUITMENT



Labour supplier to the tunnelling industry

[www.reliablecontractors.co.uk](http://www.reliablecontractors.co.uk)  
[info@reliablecontractors.co.uk](mailto:info@reliablecontractors.co.uk)  
01843 294546

**RC** Reliable Contractors LTD

MICROTUNNELLING

WHEN THE GOING GETS TOUGH...  
...Iseki microtunnelling machines come smiling through!

Microtunnelling equipment - for hire or sale



Iseki Microtunnelling  
Wellingborough UK  
+44(0)1234 781166  
[www.isekimicro.com](http://www.isekimicro.com)

MONITORING EQUIPMENT



Tunnel Atmosphere Monitoring

- Carbon Monoxide
- Nitric Oxide
- Nitrogen Dioxide
- Visibility
- Air Flow & Direction

Low cost high precision tunnel sensors proven over 20 years

**CODEL International Ltd**  
+44 (0) 1629 814351  
[sales@codel.co.uk](mailto:sales@codel.co.uk)  
[www.codel.co.uk](http://www.codel.co.uk)

World leaders in tunnel atmosphere monitoring

SEGMENT FITTINGS



**TTC**  
TECHNICAL TUNNELLING COMPONENTS

PLASTIC COMPONENTS FOR SEGMENT CONNECTION  
BUILDING AND GROUTING SYSTEMS

[WWW.TTCLTD.ORG](http://WWW.TTCLTD.ORG)  
+44(0)1455 234401

MONITORING SYSTEMS



**Getec**

Liquid Level Settlement Cells • Monitoring Software • Instrumentation  
[www.getec-uk.com](http://www.getec-uk.com)

PRECAST CONCRETE



**MACRETE**

028 7965 0471  
[www.macrete.com](http://www.macrete.com)

Specialists in precast tunnel and shaft systems

TUNNELLING SUPPLIES



**TA Tunnelling Accessories**

EPDM GASKETS  
PLASTIC SEGMENT FITTINGS  
FOAMS & POLYMERS  
HYDROPHYLIC RUBBER  
BOLTS  
PACKERS  
LIFTING EQUIPMENT

BULLFLEX  
SEALING STRIPS  
SECONDARY SEALS  
TBM LAUNCH SEALS  
LUBRICANTS  
ROLLING STOCK

+44 (0) 1424 854112  
[info@tunnellingaccessories.co.uk](mailto:info@tunnellingaccessories.co.uk)  
[www.tunnellingaccessories.co.uk](http://www.tunnellingaccessories.co.uk)

MONITORING SYSTEMS



**SIGGEO** DELIVERING SOLUTIONS

GEOTECHNICAL INSTRUMENTS AND STRUCTURAL HEALTH MONITORING

[WWW.SIGGEO.COM](http://WWW.SIGGEO.COM)  
Via F. Serpero 4/F1  
20060 Masate (MI) - Italy  
Phone +39 02 95764130  
[INFO@SIGGEO.COM](mailto:INFO@SIGGEO.COM)

To advertise in the Business Directory contact Tom Willard on +44 203 096 2608 or email [twillard@tunnelsonline.info](mailto:twillard@tunnelsonline.info)  
Rates, series bookings and dimensions available on request

TUNNEL DESIGN



Tunnel Design  
Technical Assistance  
Monitoring  
ADECO-RS® approach

**Rocksoil**  
S.p.A.

Tel: +39.02.65.54.323  
e-mail: [rocksoil@fin.it](mailto:rocksoil@fin.it)  
<http://www.rocksoil.com>

VENTILATION



**SCHAUENBURG**  
TUNNEL-VENTILATION GMBH

Flexible Ventilation Ducting

[www.tunnel-ventilation.de](http://www.tunnel-ventilation.de)  
Phone: +49 208 8827610  
Fax: +49 208 8827615

Global Tunnelling Experts.  
Bringing the best together.



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

Global Tunnelling Experts  
+31 (0) 10 266 94 44  
[clients@global-tunnelling-experts.com](mailto:clients@global-tunnelling-experts.com)  
[www.global-tunnelling-experts.com](http://www.global-tunnelling-experts.com)

The Netherlands | Germany | United Kingdom  
Panama | Denmark | Australia



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



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

Pioneers in development and sustainability  
[www.acciona.com](http://www.acciona.com)  
+44 (0)203 755 5321

Steve Woodrow  
[steve.woodrow@aecom.com](mailto:steve.woodrow@aecom.com)  
+44 (0) 208 639 3500  
Mark Round  
[mark.round@aecom.com](mailto:mark.round@aecom.com)  
+44 (0) 121 214 8103  
[www.aecom.com](http://www.aecom.com)

Tunnel and Shaft Design.  
Temporary Works Specialists.  
[www.alanauld.com](http://www.alanauld.com)  
+44(0) 1302 329 911

T: +44 (0)20 7636 1531  
E: [london@arup.com](mailto:london@arup.com)  
W: [www.arup.com](http://www.arup.com)



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

Delivering value across the construction cycle.  
[www.lbassoc.co.uk](http://www.lbassoc.co.uk)

Gill Baker  
01788 534586  
[info.tunnelling@morgansindall.com](mailto:info.tunnelling@morgansindall.com)  
[morgansindall.com](http://morgansindall.com)

Mark Leggett  
T: +44 (0)20 8774 2758  
E: [mark.leggett@mottmac.com](mailto:mark.leggett@mottmac.com)  
[www.tunnels.mottmac.com](http://www.tunnels.mottmac.com)

01226 381133  
[www.naturalcement.co.uk](http://www.naturalcement.co.uk)

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

Website  
[www.atlascopco.co.uk/underground](http://www.atlascopco.co.uk/underground)  
Email  
[ac.cmtuk@uk.atlascopco.com](mailto:ac.cmtuk@uk.atlascopco.com)

We create chemistry  
[www.ugc.basf.com](http://www.ugc.basf.com)

Peter J Wright  
+44 (0)20 3479 8660  
[Peter.Wright@ch2m.com](mailto:Peter.Wright@ch2m.com)  
[www.ch2mhill.com](http://www.ch2mhill.com)

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

+44 (0)20 7099 2608  
[enquiries@otbeng.com](mailto:enquiries@otbeng.com)  
[www.otbeng.com](http://www.otbeng.com)

DESIGN • CONSULT • MANUFACTURE  
TRACKING • SAFETY • DATA • COMMUNICATION  
TESTING & COMMISSIONING  
[www.pbegrp.com](http://www.pbegrp.com)  
UK: +44 1908 691 685  
US: +1 276 988 5505

Tunnel Control Systems  
/ Design / Install  
/ Consult / Commission  
/ Manage / Maintain  
**PDS**  
+44 (0) 1332 280195  
[www.pdslimited.co.uk](http://www.pdslimited.co.uk)

Stephen Meadowcroft  
T: +44 (0)162 884 2444  
E: [stephen.meadowcroft@costain.com](mailto:stephen.meadowcroft@costain.com)  
[www.costain.com](http://www.costain.com)

[enquiries@dannysullivan.co.uk](mailto:enquiries@dannysullivan.co.uk)  
+44 (0)20 8961 1900  
[www.dannysullivan.co.uk](http://www.dannysullivan.co.uk)

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

T. +44 208 339 7090  
E. [london@dr-sauer.com](mailto:london@dr-sauer.com)  
[www.dr-sauer.com](http://www.dr-sauer.com)

[www.porr-group.com](http://www.porr-group.com)

TEMPORARY ELECTRICAL EQUIPMENT & CABLES FOR TUNNELLING & CONSTRUCTION  
TEL: +44 (0) 1206 596 100  
[info.uk@rutherfordgp.com](mailto:info.uk@rutherfordgp.com)  
[www.rutherfordglobalpower.com](http://www.rutherfordglobalpower.com)

[www.shaymurtagh.co.uk](http://www.shaymurtagh.co.uk)

Plant & Equipment Sales + Hire  
Contract Works - Labour Supply  
[www.shotcrete.co.uk](http://www.shotcrete.co.uk)

For all your Microsilica needs, contact Elkem Ltd:  
01142 700334 or directly to [john.finch@elkem.no](mailto:john.finch@elkem.no)  
[www.elkem.com](http://www.elkem.com)

Tel: 01455 290780 Mob: 07850 234 136  
[scarson@fpmccann.co.uk](mailto:scarson@fpmccann.co.uk)  
Web: [www.fpmccann.co.uk](http://www.fpmccann.co.uk)

[enquiries@galldris.co.uk](mailto:enquiries@galldris.co.uk)  
01992 763000  
[www.galldris.co.uk](http://www.galldris.co.uk)

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

call +44 (0)1565 633111  
[email.info@stirlinglloyd.com](mailto:email.info@stirlinglloyd.com)  
or visit [stirlinglloyd.com](http://stirlinglloyd.com)

Tunnelling works:  
world class innovative solutions  
[www.vinci-construction-projects.com/british-isles](http://www.vinci-construction-projects.com/british-isles)

TUNNEL SEGMENT GASKETS  
T: +44 (0)1480 411333  
E: [sales@vip-polymers.com](mailto:sales@vip-polymers.com)  
[www.vip-polymers.com](http://www.vip-polymers.com)

Global consultants, designers, engineers and programme managers  
[wspgroup.com](http://wspgroup.com) [pbworld.com](http://pbworld.com)  
Roger Yenn  
Director of Ground Engineering  
+44 (0)7876-260-004 - [roger.yenn@pbworld.com](mailto:roger.yenn@pbworld.com)

Providing soil, rock and aggregate laboratory testing services since 1995  
+44 (0)1923 892 190  
[admin@geolabs.co.uk](mailto:admin@geolabs.co.uk)  
[www.geolabs.co.uk](http://www.geolabs.co.uk)

[grace.com/DeNeef.Stop.Leaks.Here](http://grace.com/DeNeef.Stop.Leaks.Here)  
**de neef**

01582 470300  
[WWW.HALFEN.CO.UK](http://WWW.HALFEN.CO.UK)

Joseph Gallagher Ltd  
Tel: +44 (0)1375 672070  
Fax: +44 (0)1375 672073  
Email: [headoffice@josephgallagher.co.uk](mailto:headoffice@josephgallagher.co.uk)

Tel: +44 (0) 1482 796214  
[info@als-europe.com](mailto:info@als-europe.com)  
[www.wwlals.com](http://www.wwlals.com)

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

# What's on

2016

## GeoChina International Conference

25-27 July 2016  
Shandong, China

This conference will provide a showcase for recent developments and advancements in design, construction, and safety Inspections of transportation Infrastructures and offer a forum to discuss and debate future directions for the 21st century. Conference topics will cover a broad array of contemporary technical issues.

[www.geochina2016.geoconf.org](http://www.geochina2016.geoconf.org)

## Urban Underground Space & Tunnelling Summit

6-9 September 2016  
Singapore

Asia's Leading Urban Underground Space & Tunnelling Summit will return to discuss leading practices, innovative techniques and sustainable solutions for design, engineering and construction of tunnels and underground space.

[www.equip-global.com](http://www.equip-global.com)

## ISOCARP Conference

12-16 September 2016  
Durban, South Africa

The International Society of City and Regional Planners (ISOCARP) is a global association of experienced professional planners. It was founded in 1965 in a bid to bring together recognised and highly-qualified planners in an international network. The ISOCARP network brings together people from more than 80 countries worldwide.

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

## No Dig Live UK

20-22 September 2016  
Peterborough, UK

Following the success of No Dig Live UK held in September 2014, the 13th biennial trenchless technology exhibition, outdoor demonstrations and seminars will return to Peterborough.

[www.nodiglive.co.uk](http://www.nodiglive.co.uk)

## Innotrans

20-23 September 2016  
Berlin, Germany

InnoTrans is the leading international trade fair for transportation technology, and takes place every two years in

Berlin, Germany. The event is subdivided into the five segments Railway Technology, Railway Infrastructure, Public Transport, Interiors and Tunnels.

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

## Nordic Grouting Symposium

26-27 September 2016  
Oslo, Norway

The Norwegian Group of Rock Mechanics (NBG) and the Norwegian Tunnelling Society (NFF) have the pleasure to announce that the 8th Nordic Grouting Symposium will take place 26-27th of September 2016. Nordic colleagues are invited to present papers and exchange experiences.

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

## Underground Singapore 2016

29-30 September 2016  
Singapore

Underground Singapore is a Conference Organised by the Tunnelling and Underground Construction Society (Singapore) and supported by the Centre for Soft Ground Engineering, National University of Singapore. The purpose of the Conference is to provide a forum for the discussion of issues relevant to the design and construction of underground works in Singapore.

[www.tucss.org.sg](http://www.tucss.org.sg)

## Expo Tunnel

19-21 October 2016  
Bologna, Italy

ExpoTunnel is an exhibition dedicated to the world of tunnelling, drilling, mining, underground construction and research. It is an opportunity to meet in a global framework of supply and demand of high technology and its field applications, with the chance to learn new methods and harness new techniques.

[www.expotunnel.it](http://www.expotunnel.it)

## TAC Conference

12-15 December 2016  
Ottawa, Canada

The Tunnelling Association of Canada is pleased to welcome you to TAC 2016 Ottawa. With the theme Capitalising on Underground Infrastructure, the 2016 TAC conference will include plenary presentations, technical sessions, and a trade exhibition all designed to highlight advancements in tunnelling.

[www.tac2016.ca](http://www.tac2016.ca)

## ITA Tunnelling Awards

10-11 November 2016  
Singapore

The ITA tunnelling awards 2016 is the second annual international competition to celebrate achievements in tunnelling and underground construction invites nominations. A two day Conference in Singapore is planned, including the Awards Conference and Banquet.

[www.awards.ita-aites.org](http://www.awards.ita-aites.org)

## Bauma China

22-25 November 2016  
Shanghai, China

Bauma China is Asia's largest and most important event for the construction industry. It attracts international buyers – a fact that guarantees a high return on your investment as well as sustainable success. The show is a platform for product presentations and a grand industry party for communication.

[www.bauma-china.com](http://www.bauma-china.com)

## TBM Digs

16-18 November 2016  
Istanbul, Turkey

Turkey has a great potential for tunnelling work, and in the near future the country is expecting to see upwards of USD 35bn of investment in the underground. The Turkish Tunnelling Society is also rapidly expanding its membership. This looks to be an impressive event following on from last year's which was hosted in Singapore.

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

## 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 and information.

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

2017

## Rapid Excavation and Tunnelling Conference 2017

9-16 June 2017  
Bergen, Norway

RETC is the only conference with a dedicated focus on the developments, technology, trends, and innovations that directly affect the tunneling and underground construction industry. It boasts an impressive programme.

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

## World Tunnel Congress

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)

## 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 experts visited Stuva Expo 2015. Preparations are already on the way for Stuva Expo 2017, which will take place in Stuttgart.

[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

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.

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

## The British Tunnelling Society

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

## The Emscher Interceptor

22 September 2016

Klaus Rieker of Wayss & Freytag will give a presentation on the construction of the Emscher wastewater tunnel over no less than 35 km from Dortmund to Bottrop. The contract was awarded to Wayss & Freytag Ingenieurbau in January 2012 and includes 47km of pipe jacking and the construction of over 100 shafts. The River Emscher in the German Ruhr District has been used for disposing of wastewater. In the early 1990s, it was decided to replace the existing open wastewater system with a sewer system and to restore the River Emscher to its natural state. The project is divided up into a number of individual contracts. Pipe jacking ranged from 1.6 to 2.8m internal diameter with interlinking conduit sections in excess of 1,100m in length.

Speaker: Klaus Rieker, Wayss & Freytag

## BTS Conference and Exhibition

11-12 October 2016

The British Tunnelling Society is pleased to announce the highlight of its 2016 events calendar. Due to be held at the QE2 Conference Centre in Westminster, the BTS Conference and Exhibition is not only the UK's largest tunneling and excavation event, it is the only event in 2016 supported by the British Tunnelling Society, making it an essential destination for senior, decision-making tunnelling professionals involved in the design, management and maintenance of today's tunneling and underground infrastructure. Presentation synopses of 250 words are now being accepted for consideration with a deadline of 26 February. For more details please visit the society website.

Please note that this event is not located in the ICE

## Over-tunnel construction at Amsterdam Station

20 October 2016

With great pressures on the use of urban overground space the need for construction directly around and over existing running tunnels has been increasing for decades. This presentation reveals the quay wall reconstruction at Amsterdam Central Station. The foundations of this quay wall intersect the north-south metro-line tunnel over a length of 600 ft. Rather than spanning the tunnel with heavy concrete slabs it "overhangs" the north-south subway line from two sides. Some piles pass at only 10 cm from the tunnel lining. The technical challenges of design and installation at such close proximity to the tunnels are discussed including the implications for taller structures.

Speaker: Robin Vervoorn, Witteveen+Bos UK

## The Crossrail experience

17 November 2016

Having completed tunnel excavation on Europe's largest infrastructure project this year, much experience has been gained by the UK tunnelling industry. This meeting will give a summary of the lessons learned from the project and follows on from a paper that was presented at the World Tunnel Congress in San Francisco earlier this year.

Speakers: Bill Tucker and Mike Black, Crossrail

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

Greg James: [greg.james@ice.co.uk](mailto:greg.james@ice.co.uk)

Paul Perry: [papy@donaldsonassociates.com](mailto:papy@donaldsonassociates.com)

# Contact us

Alex  
Conacher



**Editor**  
Alex Conacher  
Tel: +44 7429 156 753  
alex.conacher@uk.timetric.com

Nicole  
Robinson



**North America Editor**  
Nicole Robinson  
Tel: +1 612 940 2780  
nicole.robinson@us.timetric.com

Sally  
Spencer



**Contributing Editor**  
Sally Spencer  
sspencer@progressivemediagroup.com

**Contributing Editor**  
Keren Fallwell  
kfallwell@progressivemediagroup.com

**Associate Publisher**  
Jon Young  
Tel: +44 20 7406 6622  
jon.young@uk.timetric.com

Keren  
Fallwell



**Group Sales Manager**  
Tom Willard  
Tel: +44 20 3096 2608  
twillard@tunnelsonline.info

Tom  
Willard



**European Sales**  
Randolf Krings  
Tel: +49 611 5324 416  
Fax: +49 611 5324 519  
t&t@emcmedia.de

**North American Sales**  
Clive Bullard  
Tel: +1 845 231 0846 Mob: +1 845 309 0892  
cbullard@cs.com

**Italian Sales**  
Davide Ferrati  
Tel: +39 331 521 8050  
d.ferrati@ad-communication.it

**Production Controller**  
Loraine Lee  
Tel: +44 20 8269 7799  
llee@progressivemediagroup.com

## Head Office

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

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

www.tunnelsonline.info  
editor@tunnelsonline.info

## Editorial

## BTS - Editorial Advisory Board

**Chairman:**  
Eddie Woods BSc, CEng, FICE

**Committee:** Keith Bowers MSc, PhD, CEng, FICE, MIMMM, FGS; Ivor Thomas BEng, LLB, CEng, FICE; Roger Margerison BSc, CGeol, FGS; Barry M New MSc, PhD, CEng, MICE; Andrew Smith BSc, CEng, MICE; Ken Spiby BEng; Roger Bridge BEng; Mark Leggett BEng, CEng, FICE; Eoin Ó Murchú BEng, MSc, DIC, CEng, MICE; Mateusz Wojtasik BEng, MSc, DIC

## Subscriptions & Reprints

Subscription prices for 12 (24) months:  
Mailed anywhere in the UK £140.00 (€225.00),  
Europe €228.00 (€365.00), USA & Canada \$298.00  
(\$476.00), Rest of the world \$304.00 (\$486.00).  
Send subscription and back issue queries to  
*Tunnels & Tunnelling* Customer Services.  
cs@progressivemediagroup.com

Tel: +44 (0) 8450 739 607 (local rate)  
cs@progressivemediagroup.com  
*Tunnels & Tunnelling* Subscriptions,  
World Market Intelligence,  
Progressive House, 2 Maidstone Road,  
Foots Cray, Sidcup, DA14 5HZ.  
Subscribe online at [www.buythatmag.com](http://www.buythatmag.com)

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

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

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

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

*Tunnels & Tunnelling International* ISSN (USPS 7330) 1369-3999 is  
published monthly by World Market Intelligence, Progressive House, Foots  
Cray, Sidcup, Kent, DA14 5HZ.

The US annual subscription price is \$283.49. Airfreight and mailing in the  
USA by agent named Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd  
Floor, Jamaica, NY 11434, USA. Periodicals paid at Jamaica NY 11431.

US Postmaster: Send address changes to *Tunnels & Tunnelling*  
International, Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor,  
Jamaica, NY 11434, USA.

Subscription records are maintained at World Market Intelligence,  
Progressive House, Foots Cray, Sidcup, Kent, DA14 5HZ.

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

metric



# ROBBINS MAKES MORE THAN GREAT MACHINES.

# WE MAKE GREAT PARTNERS.

Robbins not only provides the best machine for your project,  
but also unrivaled support from project onset to machine  
buyback, and everything in between. There are no guarantees  
when you're underground - except that Robbins will be with  
you at every turn.

**Robbins**  
RELIABLE | RESPONSIVE

THEROBBINSCOMPANY.COM



## Tested for total safety The proven solution for tunnel ventilation systems



### TROX tunnel dampers for underground transport systems

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



**TROX**® **TECHNIK**

The art of handling air

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