INTERNATIONAL EDITION
September 2016

Tunnels AND TUNNELLING

FLOATING TUNNELS

Norway is exploring some interesting infrastructure solutions

Explosion prevention

Norway

Dust control

GETTING BOTH SIDES

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

IN MID-AUGUST the construction union UCATT issued a statement saying that Laing O'Rourke's new safety policy 'safety differently' could erode the foundations of health and safety culture. It further argued that the company's new director of health and safety for construction, Andy Sneddon, wants to impose detrimental views from Professor Sidney Dekker "who advocates sweeping away a lot of the detail in health and safety provision, and just concentrating on saving lives". This, it said, neglected the impact of more minor workplace injuries on workers' lives.

A Laing O'Rourke spokesperson said it was the first the company had heard of UCATT's comments, that the group had not approached the business with any concerns prior to reading about them in media.

The company then gave an unusually detailed response to the accusations for journalists. Typically a response runs to "we reject this accusation and will make no further comment at this time". So it's refreshing to actually see a company come out and state its case when it comes under attack.

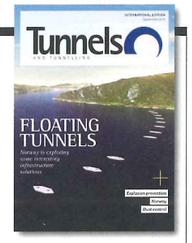
The spokesperson said that the Group's health and safety director returned to the UK from Australia last year having been working with the operations and management teams there to change what was apparently the worst performing part of the business in terms of accident frequency rate into the best. The actual change claimed by Laing O'Rourke is 3 per 100,000 hours worked down to 0.7. This was apparently achieved by applying European techniques for leadership engagement, technical controls, better equipment and better training to Australia. However, the statistics eventually plateaued and the company decided a change was needed.

"There is a focus at many organisations on low-consequence events, like twisted ankles, in the belief that they prevented high-consequence events. In other words, the prevention of all harm means the prevention of serious harm. We do not believe that is true. There is no correlation between the number of times people twist their ankle and whether or not someone's going to get killed by falling from height, for example.

"There's also a new emphasis on seeing our people as the solution to health and safety challenges by involving them in deciding how hazardous work should be approached. Instead of being all paperwork and process, we want health and safety to be at the very core of what we do – and how we do it. Safety is an ethical responsibility not a bureaucratic activity."

It seems a number of companies are entering a new era of health and safety processes and controls. Readers may also be interested in the recent health and safety changes at Joseph Gallagher (see July 2016, p.35)

Cover
This issue we look to the Norwegian tunnelling market as it prepares to host WTC 2017



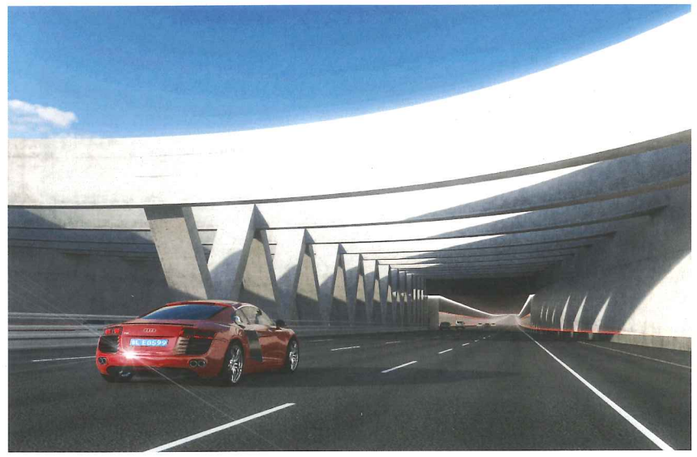
Next issue
In the next issue of Tunnels and Tunnelling we have an overview of the North American tunnelling market, a paper on the risidual strength of SFRC linings and follow up reports from the Follo Line in Norway and the Stockholm bypass in Sweden

This month...

20 YEARS AGO
NATM has become the subject of more public debate with its proposed use on Dublin's northern Port Access Tunnel being criticised by Irish politicians. Four members of the Irish Republic's parliament, representing the district under which the road tunnel will pass, have cited the record of collapses associated with NATM to back their claims that the method has inherent technical weaknesses. However, engineers point out that the tunnel will not be bored through soft ground normally associated with NATM failures. The choice of NATM is understood to be important for the viability of the USD 225M project since it has resulted in savings in the region of USD 30M.
Tunnels and Tunnelling, September 1996, p.9

30 YEARS AGO
Something of a minor revolution has overtaken the art of tunnel blasting in Norway during the last year. Explosives can be easily diluted with a cheap plastic filler made in the form of hollow polyethylene granules called Isopur. The technique, which has been known for some years, has not been applied until now because of the difficulty in mixing the very light granules with the heavier ammonium nitrate and fuel oil (Anfo) explosive. Success came when Norwegian company Dyno produced a mixer that works satisfactorily to produce the explosive called Isanol. In Norway, Isanol is about a quarter of the price of dynamite.
Tunnels and Tunnelling, September 1986, p.9

25



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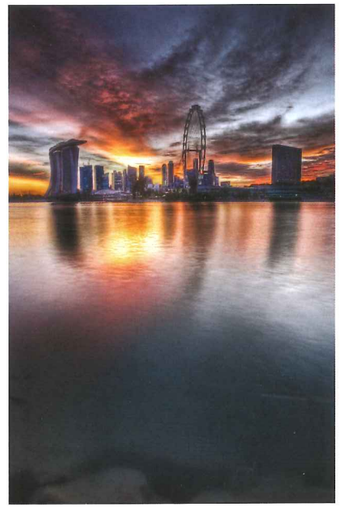

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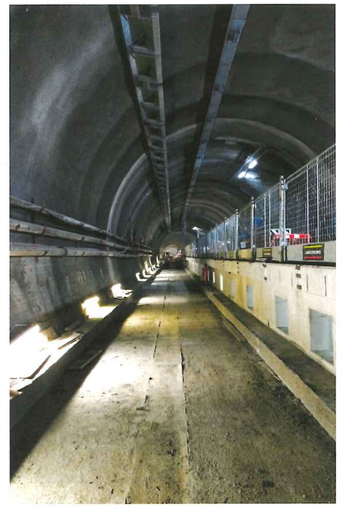


Key people in this issue

DONALD LAMONT, HYPERBARIC & TUN. SAFETY

ANGUS MAXWELL, MAXWELL GEOSYSTEMS

ANMOL BEDI, BEDI CONSULTING

BHARATH BELLE, ANGLO AMERICAN COAL

ADAM FOULSTONE, ANGLO AMERICAN COAL

THOR SKJEGGEDAL, NFF

EIVIND GROV, NTNU

KJERSTI DUNHAM, STATENS VEGVESEN

HANS-EGIL LARSEN, STATENS VEGVESEN

News

Reports

Events and contacts

ALASKAN WAY TBM FINISHES MAINTENANCE STOP

USA – Seattle Tunnel Partners (STP) resumed mining on 18 July that following a month of routine and hyperbaric maintenance on the TBM mining the SR99 tunnel, the Washington Department of Transportation said (WSDOT).

Crews inspected and repaired machine components as needed during the maintenance period, which started on June 23. WSDOT said the maintenance period included more than 40 shifts of work under hyperbaric conditions, changing cutting tools and performing other maintenance in the space behind the cutterhead.

In all, STP changed 33 of more than 700 cutting tools.

Tunnelling is one-third complete. The machine is currently approximately 120ft (36.6m) deep and will eventually reach a depth of 200ft (60m) along its alignment.

STP expects to stop two more times for maintenance before they reach the future north portal. STP is a joint venture of Dragados USA and Tutor Perini.

The view of the machine following the maintenance stop. PHOTO: WSDOT

PJA releases research

GREAT BRITAIN – The Pipe Jacking Association (PJA) has published a thesis it sponsored to its website. The topic is the disaggregation of soil during slurry pipe jacking. The Geotechnical Engineering Research Group at City University, London, originally published the thesis, which was submitted for a PhD by Neil Phillips.

The thesis can be downloaded from the research section of the Pipe Jacking Association website: www.pipejacking.org

The abstract summarising the research reads as follows:

Pipe jacking is an environmentally friendly technique for the installation of services and utilities, which leads to minimum disturbance during installation. It is an important construction method for urban environments where disruption to transport is expensive. The need to tunnel through varying geologies requiring support during tunnelling has led to the increased use of slurry tunnel boring machines. The slurry is used to stabilise the tunnel face and transport the excavated spoil to the surface. The research detailed in this dissertation assesses the magnitude of soil disaggregation during the excavation and pumping of the arisings within the slurry to the separation plant. The two main objectives were to create a mixing test that would allow the disaggregation of the soil to be predicted prior to specification of the separation plant and to link the results of this test to typical soil properties. In addressing the second objective efforts have also been made to characterise the different mechanisms of disaggregation observed in the mixing tests. The typical soil testing methods used to classify the soil samples were; Atterberg limits, particle size distributions, unconfined compressive strength, mineralogy (XRD) and chemical analysis (XRF).

A mixing test has been designed using a Hobart planetary mixer to classify the amount of soil cuttings that disaggregate during mixing with a slurry fluid. This test was found to produce repeatable results using Speswhite Kaolin samples and then used to assess the differences in disaggregation rates of London Clay, Upper Mottled Beds and Fleetwood Silts. In total 71 mixing tests were completed during the development of the test and the classifying of the soils. The test involved mixing distilled water with 10 clay cuttings for varying times. The resulting solid particles were then sized through a series of sieves and sedimentation tests carried out to produce a particle size distribution of the resulting soil. The mixing tests showed the Upper Mottled Beds to have the highest rate of disaggregation, with the Fleetwood Silts displaying the least. This has been attributed to the level of cementing within the soil and the microstructure of the clay and silt sized particles.

The liquidity index and initial soil strength were not found to be important factors in the predicting the rate of disaggregation of a particular soil type, but were significant for some soils. The Fleetwood Silts had the lowest unconfined compressive strengths but also produced the least amount of disaggregated soil. The soil macrofabric, although not quantified, also appeared to have an effect on the rate of disaggregation of a particular soil. An increase in discontinuities within the sample produced more cuttings larger than 4.75mm but a lower amount of 63µm sized fraction disaggregated.

In addition to the mixing tests carried out using water, a series of tests were completed using a polymer based slurry, HydroCut CF. This showed mixed results; The polymer prevented any clay or silt sized particles from passing through the 63 µm sieve. However, there was no overall reduction in disaggregation and a large increase in the time it took to sieve the slurry.

Black & Veatch grows water staff

USA – Black & Veatch announced August 11 it has hired or relocated an additional six engineers for its water and wastewater business at the company's Houston regional office to support project growth in Texas and globally.

The newly hired or relocated engineers include Fariborz Fakheri, project manager; Sergio Flores, civil engineer; Andrew Issazadeh, civil-structural engineer; Justin Sandt, civil engineer; Jose Mendiola; civil engineer; and Corey Evans, civil engineer.

Three teams shortlisted for Melbourne's Metro Tunnel

AUSTRALIA – Victoria announced on 11 August that three consortia have been shortlisted to build Melbourne's Metro Tunnel and five new underground stations. The AUD 6bn (USD 4.62bn) PPP is biggest public transport project in Victoria.

- Continuum Victoria – comprising Acciona Infrastructure, Ferrovial Agroman, Honeywell, Downer EDI and Plenary Origination
- Cross Yarra Partnership – comprising Lendlease Engineering, John Holland, Bouygues Construction and Capella Capital
- Moving Melbourne Together – comprising Pacific Partnerships, CPB Contractors, Ghella, Salini Impregilo, Serco and Macquarie Capital

The Metro Tunnel will create 4,700 jobs and free up space in the City Loop to run more services in and out of the City on lines across the network, benefiting passengers across Melbourne.

The public private partnership will build and fit-out the 9km Metro Tunnel and the five new underground stations at Arden, Parkville, CBD North, CBD South and Domain. Up to six TBMs will be used for the tunnel project.

Victoria premier Daniel Andrews said,"The best construction companies in the world are lining up to build the biggest public transport project in Australia – the Metro Tunnel."

Shortlisted bidders for the PPP will be asked to submit a formal proposal by early next year, with a contract expected to be awarded by the end of 2017.

Work on the Tunnel and Stations PPP will begin in 2018.

Munfah heads up tunnelling business at WSP PB

USA – Nasri Munfah has been appointed a senior vice president and director of global tunnelling at WSP Parsons Brinckerhoff, the company announced on 1 August.

In his new position, Munfah will be responsible for developing a long-term strategic plan to advance the firm's tunnelling practice nationally and globally. He will provide leadership in project delivery, marketing, recruitment and professional development of staff, acquisitions, and teaming opportunities with other firms.

Munfah has more than 30 years of experience in tunnelling and underground engineering and project management experience in transportation, transit and underground engineering. He has been responsible for managing all phases of multi-billion-dollar, multidisciplinary domestic and international tunnelling and transportation projects from feasibility and conceptual engineering through final design and construction.

He is a principal investigator and a co-author of Federal Highway Administration Tunnel Design Manual, the first comprehensive manual for tunnel design in the USA.

Munfah rejoins WSP Parsons Brinckerhoff from an international engineering firm, where he served as chairman of the global tunnel business practice.

From 1970 through 2004, he was a vice president, senior technical manager and senior engineering manager with Parsons Brinckerhoff, serving as project manager, project director and principal-in-charge on tunnelling projects worldwide.

FUGRO PERSONNEL NET ROLES IN GROUND INVESTIGATION BODIES

GREAT BRITAIN – Engineers and managers from Fugro Geoservices have been appointed to prominent positions in two prominent geosciences bodies. John Grainger, manager of the company's drilling service, was made a director of the British Drilling Association (BDA).

Grainger is a chartered engineer and chartered geologist with 35 years of experience in drilling and ground investigation. He previously served as BDA chair and currently chairs its marketing committee.

On the appointment, Grainger said: "It is a huge privilege to take on this key role with the British Drilling Association as it marks its fortieth year. I will be bringing all of my professional experience to ensure the Association continues to push the boundaries of drilling competence, safety and achievement with members and UK practitioners and for the benefit of the wider global drilling industry."

Other Fugro personnel co-opted to BDA roles are Neil Breach, a safety advisor who joins the safety subcommittee, and senior project engineer Paul McMann who now serves on the training and education subcommittee.

Meanwhile, Chris Coleman, a principal engineering geologist has been elected to the committee of the Engineering Group of the Geological Society (EGGS). Coleman is a chartered geologist and technical lead for onshore and nearshore site characterisation. He is a specialist in Quaternary deposits and terrains, investigation of intertidal zones, and development of 3D ground models for geohazard visualisation and engineering appraisal.

Coleman commented: "I am delighted to participate in the Engineering Group which plays a pivotal role in training and professional standards in the field of engineering geology."

Chris Coleman

John Grainger

The BDA represents drilling contractors and specialists in the UK geotechnical and ground investigation industry.

The EGGS is the main focus for engineering geology in the UK and represents the Geological Society on the Ground Forum, the umbrella organisation for professional bodies and trade associations in ground engineering.

Fugro GeoServices is an offshore survey company specialising in marine geophysics and seafloor mapping services. In terms of underground construction, the company informs the designers of offshore tunnels and pipelines.

Pöyry awarded contract for Rhine tunnel

GERMANY – Switzerland's Federal Roads Office (FEDRO) has awarded a basic engineering services assignment to an engineering consortium led by Pöyry for a new tunnel under the Rhine, aimed at reducing traffic congestion, the company announced on 27 July. The new tunnel would aim to relieve the A2 motorway in Basel which suffers from significant congestion, with the Schwarzwaldtunnel – Hagnau – Augst section particularly affected.

With increasing volumes of traffic and no relief in sight, the aim is to provide a new transport link between Birsfelden, a town to the east of Basel, and the northern section (Rhine tunnel) of the main A2 motorway to/from Germany and France.

The basic engineering services assignment will aim to determine the optimal lines of the new tunnel connections and the overall feasibility of the project. The assignment is expected to be completed in 2021.

Building tunnels in urban environments can be particularly challenging due to the limited amount of available space.

"The use of mild construction methods with the aim of affecting traffic and residents' quality of life as little as possible is at the same time of major importance. We are pleased to bring our experience in tunnel planning and realisation in the inner-city area to this project," declares Nicolas Hessler, head of Pöyry Switzerland's Tunnel Construction Section and project manager.

The value of the order is not disclosed. The order has been recognised within the Regional Operations Business Group order stock in Q2/2016.

Xe-Pian Xe-Namnoy hydropower project TBM passes halfway

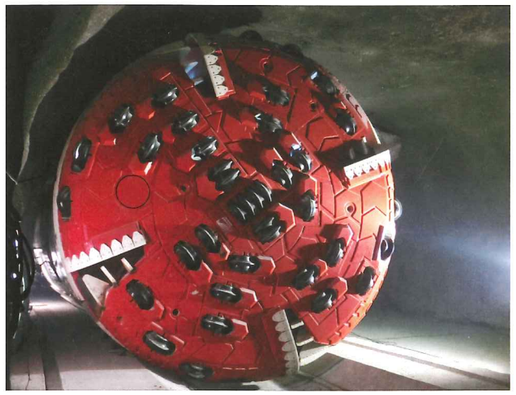
LAOS – The TBM boring the Xe-Pian Xe-Namnoy project passed the halfway point in early July. The TBM, a 5.74m-diameter double shield, was manufactured by Terratec and launched from an 500m-long adit constructed by drill and blast in summer 2015.

By July of this year it had bored 6.4km of the 11.5km tunnel.

Following completion of the remaining distance due by early 2017, contractor Seli Overseas will hand over to main contractor, SK Engineering and Construction.

A spokesman for the manufacturer said of the geology: "The TBM has been boring through different formations, mainly mudstone, sandstone and siltstone with an average UCS of 80MPa and peaks up to 200MPa.

"The TBM has gone through fractured zones as well and crossed 3 faults successfully on its way."



The Xe-Pian Xe-Namnoy project looks set to conclude tunnel excavation by early 2017

DRAGADOS TO BUILD THE THIMBLE SHOAL CHANNEL TUNNEL

USA – The Chesapeake Bay Bridge and Tunnel (CBBT) Commission announced July 27 it awarded the Dragados Team a contract to construct a new parallel tunnel at the Thimble Shoal Channel.

The Dragados Team, a joint venture composed of Dragados USA, Inc., and Schiavone Construction Company LLC, submitted the lowest price proposal at USD 755,987,318.

The Dragados Team's proposal included a bored tunnel and construction will begin on Island 1 in the fall of 2017. Total construction of the parallel tunnel at the Thimble Shoal Channel is expected to take approximately five years.

According to CBBT, on May 27 the commission invited each of the three teams that had submitted fully-compliant proposals by the original due date of April 29 to submit revised proposals for a re-scoped project after all of the original price proposals exceeded the cost estimate.

It said, "The re-scoping of the project was focused solely on the reduction of costs by reducing or eliminating non-critical elements of the project without compromising the technical safety factor of the design, customer safety, and maintenance life cycle priorities that are specified in the technical requirements of the RFP documents."

The conceptual design for the project RFP initially included the widening of the man-made islands 250ft to the west of the existing islands to provide physical space for either an immersed tunnel or bored tunnel to transition to the existing trestle alignment of the CBBT.

Jeff Holland, executive director of the CBBT, stated that "the project was originally envisioned with a substantial expansion of the portal islands. As such, the expanded southern island would have created space for the future public amenities at little additional cost.

"When all of the teams competing for the project focused on reducing cost, it became apparent that island expansion could be very limited or non-existent. As a result, the inclusion of the space sizing for the public amenities of a restaurant, retail shop and 200 additional parking spots that would otherwise require substantial island expansion became cost prohibitive and not necessary to meet the basic mission of the CBBT: providing the traveling public with a safe, cost effective, and unique driving experience across the scenic Chesapeake Bay."

This scope change, combined with others, allowed the commission to reduce the cost of the Project by nearly USD 260M from the low price received during the first phase of design-build proposal prices.

Tunnelling to resume on the Ottawa LRT

CANADA – Steve Cripps, director of Ottawa's Rail Implementation Office Transportation Services Department released a memo on Friday to the mayor and city council confirming tunnelling will resume this week on the LRT project, following the 8 June sinkhole on Rideau Street.

"This weekend RTG will resume work beneath Rideau Street between the Rideau Station cavern and east of Sussex Drive," Cripps said. "This work is in preparation for the resumption of tunnelling which will begin early next week. Approximately 50m of excavation remains to complete the 2.5km tunnel."

A majority of construction activities have resumed around Rideau Street, and water main and utility repairs are completed in the Rideau and Sussex streets area.

The Rideau Station west entrance has been repaired, sidewalks are open to pedestrians and the roadway has re-opened to transit services and taxis. Work at the Rideau Station cavern, west entrance and east entrance is also underway.

The memo outlined measures in place to monitor progress and mitigate potential risk:

- The City of Ottawa, RTG and their tunnelling experts will be on-site, both above ground and within the tunnel, monitoring activities.
- In accordance with the sequential excavation method (SEM), the tunnel will be mined in small pockets.
- Additional supports including pipe roofing, lattice girders and face bolts will be installed to reinforce the tunnel. Systematic drainage and grouting (injection of concrete to reinforce the area) will occur to mitigate any loose or potentially unstable ground.
- Monitoring of the ground and adjacent buildings will remain ongoing with increased monitoring of the newly installed water mains to detect any settlement or leaks.

Overall, the construction of the Confederation Line LRT project remains on schedule.

Hayward Baker expands in New Orleans

USA – Hayward Baker announced July 31 the opening of a new office location in New Orleans, Louisiana. The new office will support customers and projects along the Gulf Coast. As an extension of the Houston office, the New Orleans office is spearheaded by recent hire Christopher Rogers, project manager with oversight from Tyson Deklavs, area manager.

Rogers is a graduate of Mississippi State University with a B.S. degree in Civil and Environmental Engineering. He is a registered engineer in Mississippi and Louisiana. Rogers has more than 10 years of diverse experience in quality control, design-build, and project management. Prior to joining Hayward Baker, Rogers worked for a general contractor in Louisiana as the senior quality control manager as well as a field project manager. He also has spent part of his career as a geotechnical consultant.

According to Deklavs, the opening of the New Orleans office represents a commitment to closer collaboration with public, commercial, and industrial Gulf Coast clients. This market includes a diverse group of general contractors, geotechnical consultants, developers, and industrial owners.

TIMELY TRIO

Donald Lamont
Donald is the director of Hyperbaric and Tunnel Safety, and the ITA H&S WG animateur

I THOUGHT THERE was an interesting and interrelated trio of topics in your July 2016 edition. One covered the issue of "Exclusion zones" and the enthusiasm with which the UK tunnelling industry has embraced them following the fatality on Crossrail. The other two topics were behavioural safety and the health risks from silica dust inhalation. No links were made between the topics – however I will endeavour to do so from the perspective of health and safety and the revision of BS 6164.

I have no doubt the current revision of BS 6164 will take due account of exclusion zones. However, I hope that in revising BS 6164 we will go further by continuing to address the whole range of health and safety risks arising from SCL tunnelling bearing in mind that many of the risks are already covered in BS 6164:2011 e.g. health risks from dust and fire risk on machinery used underground.

It is never acceptable to work under unsupported ground without further protection in place. The Crossrail guidance on "exclusion" zones is quite clear on that. However, I can't help but feel that part of the rationale behind the setting up of "restricted" zones was to use health and safety to keep out the many visitors making no direct contribution to the tunnelling works, "tunnelling tourists", which Crossrail unfortunately had to accommodate.

One of the potential unintended outcomes in H&S terms from having restricted zones of any sort, is that those allowed into them can become inured to the risks involved, feel they are in some way less susceptible and go on to adopt a more casual attitude to the risk mitigation measures.

Another unintended interpretation which regulators and lawyers can adopt is to infer that restricted zones are by implication areas of heightened risk.

This then leads to the question – "What additional measures have been put in place to mitigate these risks?". I hope that in this respect BS 6164 will provide some guidance as the enforcement of restricted zones does not in itself mitigate any of the risks which arise in these zones and affect those in them.

Arguably, even if restricted/exclusion zones had been in place prior to the Fisher Street fatality they would not have prevented it. The "barriers" which are currently used are more demarcation lines than substantial physical barriers which provide any meaningful restriction to access. This is where behavioural safety has a major part to play in creating the culture in which everyone recognises that although the barriers provided are easily bypassed, to do so is an unacceptable and highly unsafe behaviour.

The life threatening consequences of silica dust inhalation were dramatically illustrated by the article on Hawks Nest Tunnel. The consequences of silica exposure and indeed any mineral dust exposure, are no less severe today than they were in the 1930s although the control measures should be better known and more effective.

Copious amounts of dust including a proportion of silica dust can be generated in different parts of the SCL cycle – excavation, the breaking out of existing temporary concrete linings and from spraying activity. All dust exposure is potentially harmful and any spraying operation, whether of shotcrete or waterproofing membrane, results in the deliberate release of dust or particulates into the tunnel atmosphere. Those in restricted zones are most at risk from dust exposure. Others, kept well back from the spraying area are much less at risk because the dust concentrations are lower and their exposure time is shorter. Poor ventilation either fails to prevent or directly causes dust to spread throughout the tunnel complex leading to secondary dust exposure affecting those not actually working at the face. Hence restricted/exclusion zones do nothing to mitigate the dust risk from SCL tunnelling particularly for those most at but more needs to be done on prevention of falls of ground or shotcrete rather than just merely keeping people out of the danger zone. More robust physical barriers are not a reasonably practicable solution in that they would pose more risk than they prevented.

Smarter use of imaging technologies for detecting persons linked to an alarm system could be one way forward particularly if used in conjunction with behavioural safety training. The purpose of restricted zone should be clarified. The enhanced risk to those at long term risk in them should be addressed by appropriate mitigation measures.

There can be a strong element of chance in the consequences of any unintended incident which can never be fully foreseen or mitigated against hence prevention/avoidance rather than mitigation is preferred.

The recent RAIB report into the Stokes Lane incident in which a train carrying around 2250 tonnes of diesel fuel derailed at a level crossing illustrates this. The derailment was as a result of track deflection arising from over-excavation of a pipejacked under track crossing. A number of tank wagons derailed at speed towards the adjacent line but fortunately no wagon overturned or entered the kinematic envelope for the adjacent line. Had they done so a catastrophe could have ensued.

Reduction in exposure to dust – silica, mineral or as particulates from membrane spraying - should be tackled more aggressively primarily through reduction of emissions at source before improved control by ventilation. Real time dust monitoring instruments are becoming available which give instantaneous dust levels and which link into existing atmospheric monitoring systems.

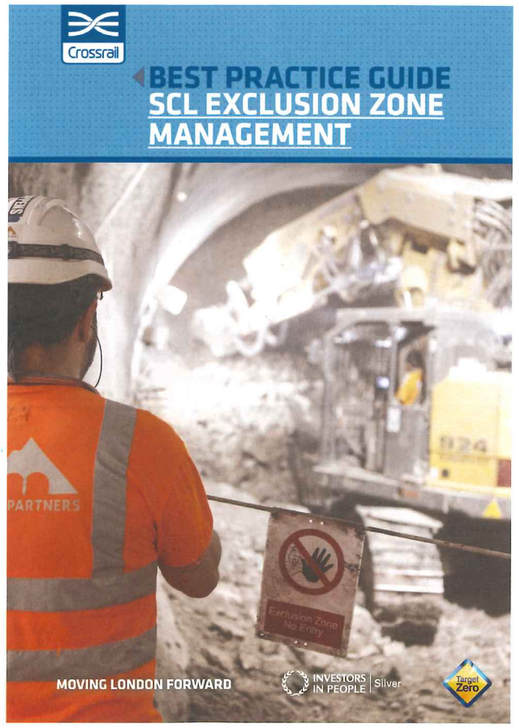
Selection of respiratory protective equipment remains a last resort in mitigating dust risk but selection of masks based on peak exposure rather than average exposure is likely to be the way forward. Norwegian research has shown that smoking exacerbates the effects of dust inhalation in tunnel workers. BS 6164:2011 already recommends that dust emissions are a mix design parameter for sprayed concrete but this has been almost totally ignored by industry to date.

This is only a specific interpretation for tunnelling of designer duties under CDM and employer duties under MHSWR.

Thus in one edition the magazine usefully highlighted three interrelated topics all of which are being addressed in the revision of BS 6164 currently being undertaken.

It is not only through BS 6164 that standards continue to be used to mitigate the risks of conventional tunnelling.
In the past year and thanks to support from ITA and BSI there has at last been some recognition in CEN and ISO of the additional risks of machinery use underground namely that construction plant and equipment intended for use on the surface should not be used underground without additional risk mitigation measures being taken and that specific machinery safety standards common to mining and tunnelling are required for specialised underground machinery such as spray robots

Donald Lamont



Left: The exclusion zones guidance was republished by T&T in July

Left: Refurb works on the Queen Street Tunnel in Glasgow were finished on 5 August, three weeks ahead of schedule according to Network Rail. Work began in March.
The project to refurbish and upgrade the 1km-long tunnel involved renewing 1,800m of concrete slab track and the installation of 4km of new rails.
According to Network Rail, station platforms and track layouts were also extended and altered. Preparations were also made for the electrification of the main Glasgow to Edinburgh main line which is due to take place next year.

URBAN UNDERGROUND SPACE AND TUNNELLING ASIA SUMMIT

Asia's Leading Urban Underground Space and Tunnelling Summit will return this month in Singapore

ASIA'S LEADING Urban Underground Space & Tunnelling Summit will return to discuss leading practices, innovative techniques and sustainable solutions for Design, Engineering & Construction of Underground Space and Tunnelling Projects.

Tunnelling and Underground infrastructure has become a worldwide trend solution to space scarcity, increase world population and urbanisation. Particularly in Asia, underground infrastructure and tunnelling construction is fast becoming a priority in a rapidly urbanising Asia. With the numerous opportunities emerging in the booming and demanding Tunnelling and Underground space industry in Asia, Equip Global announces that Urban Underground Space and Tunnelling Asia Summit 2016, in Singapore will be held on 6 to 9 September 2016.

Urban Underground Space and 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. This will be discussed through a series of case study presentations, underground space/ tunnelling project updates and expert panel discussions and workshop sessions.

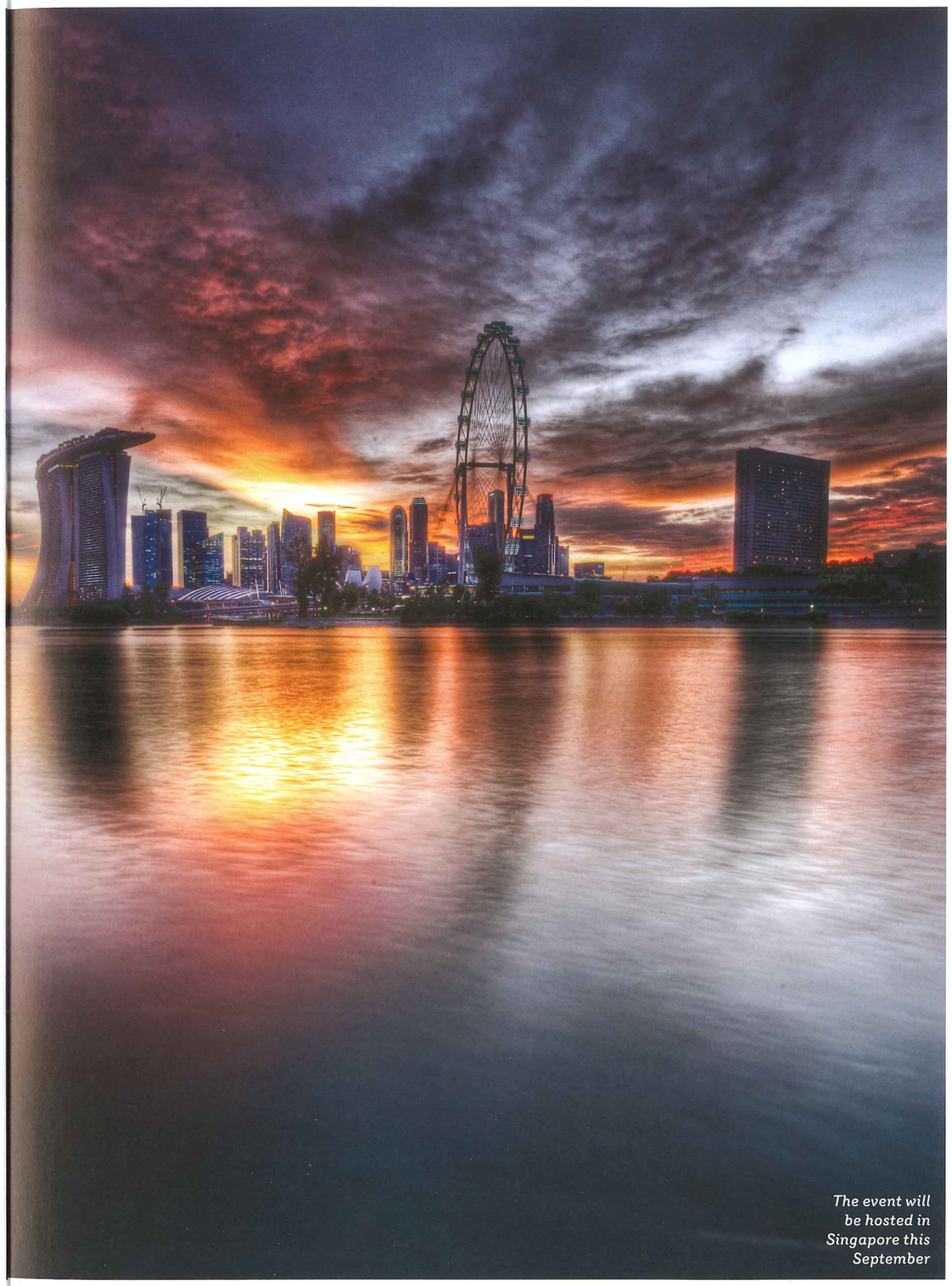
Attend Urban Underground Space and Tunnelling Asia Summit 2016 and learn best practice techniques and strategies from global experts, and implement these in your projects

When and where

Dates: 6–9 September
Venue: Furama Riverfront Hotel Singapore
405 Havelock Road, Singapore 169633

Summit highlights

- 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
- 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
- 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
- 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
- In-depth Workshops Attend 4 expert-led Workshops to 5 grasp the nuts and bolts of underground space construction and tunnelling



The event will be hosted in Singapore this September

NORWEGIAN NOUS

The Norwegian tunnelling sector is seeing many positive trends. According to annual tunnelling statistics there is a steady increase in excavated volume over the last decade. **Paola De Pascali** reports

THE NORWEGIAN TUNNELLING MARKET is booming with a lot of upcoming projects for road, rail and tunnels. Two of the main projects are the coastal highway route E39, crossing the Sognefjord with a budget of more than EUR 40bn (USD 44.7bn), and the Follo Line tunnel, which includes four sub-projects with a total value of EUR 950M (USD 1.06bn).

Thor Skjeggedal, general secretary at the Norwegian Tunnelling Society (NFF), also mentions other projects: "It has been just completed a joint rail and road project along the lake of Mjøsa. The new four-lane highway is long 17km and the double track railway line is about 15km. The total cost of this project was approximately EUR 1bn (USD 1.12bn).

"Another project to be completed is the Farriseidet - Porsgrunn double track railway line with seven tunnels of total lengths of 15km for a total investment of EUR 750M.

"The biggest on-going project is the 20km-long Follo Line tunnel. The assembly of four 9.96m-diameter double shield TBMs are continuing to excavate and the first will start boring in September this year.

"Other on-going projects are the Ryfast road tunnel system near Stavanger with a total length of 52km for a total investment of EUR 1bn. This project is scheduled to be open for traffic in 2019 and it will be the deepest subsea road tunnel ever built, reaching 292m below the sea level.

"Outside of Bergen the E16 highway is under rebuilding to include about 32km of new tunnels. There is also the upgrading of the Ulriken railway line with about 7.8km of new tunnel mostly excavated by an open TBM."

Looking at the tunnelling statistics, Skjeggedal says, tunnels for highway have had the highest volume of excavated material in 2015 with 4,453,780 cbm. "In 2015 tunnel work for hydropower projects was the second largest end-use sector, but this trend is prone to change year by year," he notes.

Eivind Grøv, a chief scientist at research organisation SINTEF and professor at the University of Science and Technology in Trondheim, adds: "The statistics show that in 2015 the total construction volume in Norway was 7M cbm of solid rock. It was 6.5M in 2014, 6M in 2012 and 2013. It has been increasing gradually for almost 10 years, starting from 4M cbm in 2003."

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

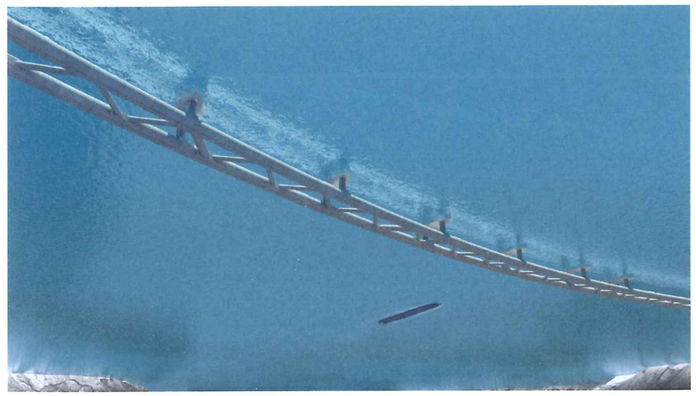
Skjeggedal also explains how the Norwegian tunnelling market is evolving with the arrival of foreign contractors. "Nowadays the major project owners go for bigger and bigger contracts. Earlier a contract of EUR 50 to 100M (USD 55.9 to 111.8M) was a big contract and they were always unit price contracts," he says. "Now we see EPC contracts of up to nearly EUR 1bn and since the local contractors are relatively small, such big contracts are challenging and risky for them. The result is that many foreign contractors are coming into the Norwegian tunnelling market, pressing the margins and that makes the local contractors less competitive."

The annual tunnelling statistics show the most active companies, indicating how much different contractors excavated over the last several years. In 2015 the main contractors were Skanska with 1,306,546 cbm, Implenia with 1,048,810 cbm, LNS with 975,132 cbm, AF with 686,255 cbm, NCC with 664,753 cbm, Kruse Smith with 536,940 cbm, Hæhre Entreprenør AS with 509,402 cbm, Marti Bau with 498,000 cbm, Ossa SA with 212,500 cbm and Veidekke 271,233 with cbm.

"Considering these statistics we can see a steady increase in excavated volume since 2001, with over 1M cbm up to 7M cbm in 2015," Skjeggedal says.

"The Norwegian government is making a national transport plan showing how communication projects are planned over the next 10 years."

Grøv adds: "In the short term there are a lot of tunnels projects coming up in the next years, particularly in connection with infrastructure projects and the hydropower sector, but it's difficult to predict in the long term how will be the infrastructure development."



Below: Concept image of a floating tunnel

TBM'S RETURN

After almost 20 years of drill and blast, TBM technology is coming back to Norway. Skjeggedal explains, "up until the early '90s about 260km of tunnels were excavated by TBMs, mainly on hydropower projects. TBMs were not used due to a strong reduction in the construction of hydropower in Norway that lasted until 2014.

"The Røssåga hydropower project required the TBM method, excavating a 7.2km headrace tunnel by a 6.2m-diameter open machine. Now the Ulriken tunnel is under construction with TBMs and the next project will be the Follo Line. However, the majority of tunnelling is still done by the drill and blast method."

Grøv adds: "The reason for the recent use of TBM technology in a few railway projects rather than drill and blast is to safely excavate parts of tunnels, side by side in populated areas with a lot of existing infrastructure assets and access constraints."

COASTAL HIGHWAY ROUTE E39

The E39 project is part of the European trunk road system and the route runs along the western coast of Norway, from Kristiansand in the south to Trondheim in central Norway with a distance of almost 1,100km. There are seven ferry connections along the route, most of which are wide and deep fjord crossings that will require huge investments and longer spanning structures than previously installed in Norway. The current travel time of some 21-22 hours between Kristiansand and Trondheim is also influenced by the overall road standard of the route.

This project has been commissioned by the Norwegian Ministry of Transport and Communications and administered by the Norwegian Public Roads Administration (NPRA) to develop the route into a more efficient corridor with no ferry connections.

E39 project manager Kjersti Kvalheim Dunham explains, "the aim of the project is to have an efficient road on the west coast of Norway because we have almost 60 per cent of Norway's traditional export from this part of the country.

*All: **Fjord crossings in Norway are resulting in some interesting solutions***

"Today the road is very narrow and small and takes too much time to connect Kristiansand and Trondheim. We want to reduce the transport time up to 10.5 hours to have a good social and industrial impact on the country."

Another objective is sustainability, and how bridge structures might be used for power generation from renewable sources such as solar energy, winds, waves and tidal currents.

Dunham says, "we started doing research and development for the coastal highway E39 program and 49 PhD students are currently working in different topics. They are also studying the environmental and the socio-economic impact of the road."

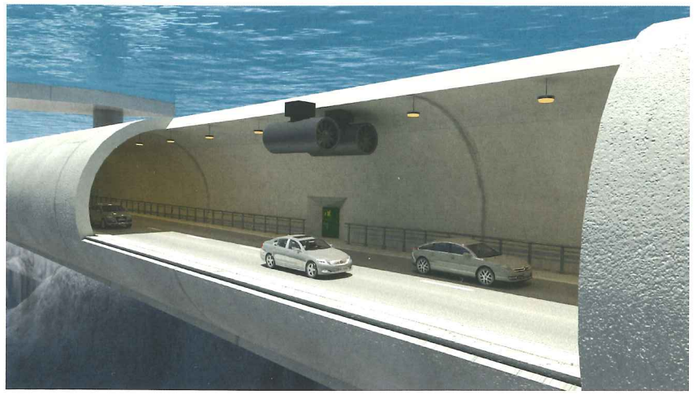
This project is exploring technical alternatives to mitigate the challenges represented by fjords.

The Sognefjord, which is about 3km wide, was used as a pilot site for developing new concepts for extreme bridges. With its vast depths of up to 1,300m and 200-300m of bottom deposits above the rock, the Sognefjord is considered one of the most difficult and challenging fjords to cross.

"We are evaluating three different bridge designs: a single span suspension bridge, a floating bridge and a submerged floating tunnel," Dunham says.

A suspension bridge across the Sognefjord would have a main span of 3,700m and this is nearly three times the length of the Golden Gate Bridge in San Francisco and double the length of the current world record. The two bridge towers would reach a height of 450m, which is 150m taller than the Eiffel tower.

Another alternative is a floating bridge, in this case a "triple spanned suspension bridge". Two of the bridge towers will stand on floating pontoons, which are anchored to the sea floor with anchors and mooring lines. Each tower will reach a height of 200m, while the pontoons are 75m in diameter and will stretch 180m down beneath the surface. This idea is taken from the offshore industry where large platforms are anchored in deep water in the same manner.



"The first study done on a submerged floating tube bridge for crossing the fjords in Norway is from the 1980s (Høgsfjord), but at that moment the technology wasn't ready to be implemented," says Arianna Minoretti, senior engineer for the E39 project.

The SFTB consists of two curved concrete tubes that are submerged in the fjord floating approximately 30m below the surface. This "tunnel" enters the bedrock beneath the surface on each side of the fjord and is anchored to floating pontoons on the surface. The tubes are approximately 4km long and are connected with trusses at regular intervals. Drivers would have the same experience driving in a submerged floating tunnel as in any other concrete tunnel. A submerged floating tunnel needs strict safety requirements similar to those that apply in ordinary tunnels. Escape routes are available through the trusses between the tubes.

"The SFTB is under evaluation for the Bjørnafjord, either with floating pontoons or tethers connecting the structure with the seabed, but we are also considering a floating bridge and a multi-span suspension bridge with towers on tension-legged platforms," Minoretti says.

Dunham adds, "we will talk about all the technical solutions at our own conference in Trondheim on 20 September (Teknologidagene), and also at the IABSE- conference in Stockholm on 22 September."

E39 ROGFAST

The E39 Rogfast is a possible crossing of Boknafjorden and Kvitsøyfjorden, north of Stavanger in the southwestern part of Norway with a sub-sea road-tunnel. The name Rogfast is an abbreviation for the Norwegian name "Rogaland fastforbindelse", translated in English as the "Rogaland fixed link". The construction will most likely start in 2017 and the budget cost is EUR 1.5bn (USD 1.68bn).

The tunnel will be approximately 27km long, expected to start in Harestad and end at Arsvågen in Bokn. The tunnel's length will be approximately 25.5km. In addition to the main tunnel there will be an arm up to Kvitsøy with a length of roughly 4km. The E39 Rogfast will be the world's longest and deepest subsea road-tunnel. Project estimates call for two, 27km reaches the depth of nearly 400m below the sea level.

E39 from Stavanger and further north is the main trunk way in the western part of Norway. E39 Rogfast will be a fast and ferry-less connection between the two cities Stavanger and Haugesund, and it will also shorten the travel time between Stavanger and Bergen.

Dunham says, "most probably this project will be excavated by drill and blast and it will be lined with concrete panel, which is quite common in Norway.

She explains the project is focusing on environmental goals as well, such making the Rogfast project carbon neutral, and even an energy producer, which could supply lighting and ventilation in the tunnel. "We aim to make different parts of E39 a Power Road, which can produce more energy than it uses," she says.

According to NGU's report (NGU: Rogfast – Norges geologiske undersøkelse, October 2014) the Rogfast tunnel goes through an area of complicated geology in the form of several thrust nappes and faults, where many types of rock are represented. Four thrust nappes, consisting mainly of granitic and dioritic gneisses, have been defined over the bedrock.

The tunnel is expected to go through phyllite and mica schist for the first approximately 6.3km from Randaberg, until it meets an expected fault zone in this area. Depending on the vertical throw of the fault, the tunnel is then expected to enter the Karmøy Ophiolite, which has gabbroic gneisses, hypabyssal rock types, volcanic rock types and sediments, as well as ultramafic rock types (dark and quartz-free). If the vertical throw is greater, the tunnel may enter the Storheia Nappe, which is composed of granitic and dioritic gneisses and lies under the Karmøy Ophiolite, or go right down to the phyllite.

Project manager at the NPRA, Tor Geir Espedal, says that a study has been conducted to address the potential for water leakage in the tunnel, based on experience from tunnels in the same area. There is experience of little leakage in phyllite and mica gneiss, while there has been moderate leakage in the other rock types, depending on the stresses and joint directions. The same study showed there is little need for injection throughout 66 per cent of the tunnel length and little to moderate need for injection over a further 27 per cent of the tunnel length.

FOLLO LINE PROJECT

As part of the largest transport project in Norway, the Follo Line consists of a 22km new double track railway line between Oslo central station and the new station at Ski, a small city south of Oslo. The Acciona Ghella joint venture will build the main part of the 20km-long tunnel, which will be Norway's longest railway tunnel to date and the longest rail tunnel in the Nordic countries.

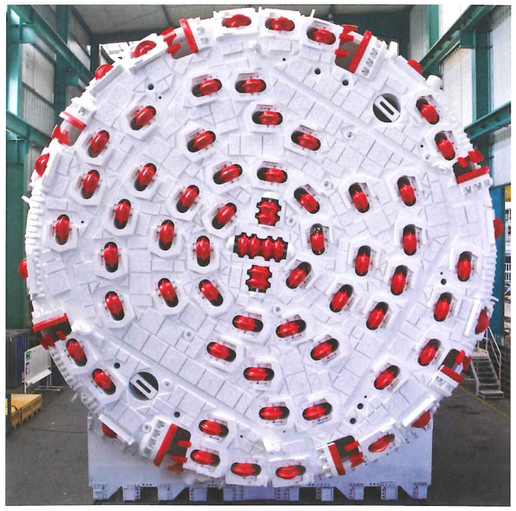
The Follo Line will be the core part of InterCity development in the south of Oslo and is commissioned by the Norwegian National Railway Administration (Jernbaneverket).

The project includes five EPC-contracts and the total cost is NOK 25bn (USD 3.03bn), financed by the Norwegian government.

The project includes the necessary realignment of tracks for the existing Østfold Line on the approach to Oslo Central station and between the tunnel and the new Ski station.

"It is important to avoid conflicts with other tracks going in or out of this busy station or with relics from the Middle Age located in that area," says Anne Katherine Kalager project manager Tunnel TBM.

The Follo Line is also designed for



speeds up to 250kph to enable a 50 per cent reduction in journey time between Oslo and Ski.

Above: A Follo Line TBM in the factory

With regard to the geology, the rocks consist predominantly of Precambrian gneisses with banding and lenses of amphibolites and pegmatite. There are also several generations of intrusions, which can be found over distances of up to 15km alongside the Follo Line tunnel. Sedimentary shale occurs in the northern part of the tunnel close to Oslo Central station.

Weaker layers of the gneiss have been more exposed to erosion, which has resulted in long, prominent ridges and valleys.

Kalager explains, "The rock mass is usually homogenous, showing good quality with moderate jointing as well. Laboratory tests illustrate that it is abrasive and strong.

"Many people will define the rock as extreme hard rock compared to what is defined as hard rock many other places in the world.

"Some groups of weakness zones intersect the tunnel alignment. The thicknesses of these zones are normally between 1 and 5m, rarely above 10m."

During several glacial periods these weakness zones have been exposed to erosion and have developed to be valleys on the rock surface. These valleys are filled with thick layers of marine sediments, mostly clay or silty clay.

Leaking into the tunnel through these weakness zones will eventually result in lowering of the pore pressure in the sediments above the tunnel. If the pore pressure is lowered in these sediments, it will cause settlements on buildings founded directly on the sediments above the tunnel. Kalager says, "one of the success criteria for the excavation of the tunnel on the Follo Line tunnel is to avoid leaking into the tunnel and development of settlements on buildings close to the tunnel.

"In order to prevent such problems, grouting will be mandatory from the TBMs in these areas," she adds. "At the early stages of the project, a huge monitoring system was established to register normal differences of the pore pressure throughout the year. All the buildings within a defined influence area have been and will be registered.

"Settlement bolts are installed at each corner of all the buildings and the buildings will be monitored before and during the construction period. The whole monitoring will give an early warning in case of water leaking, reduction of the pore pressure and development of settlements during the construction of the tunnel. Necessary mitigations, as pre-excavation grouting or infiltration of water may be implemented to prevent damages on buildings."

Kalager also describes how the tunnel will be excavated and lined. In the northern part of the tunnel section, both the Follo Line and the relocated Østfold Line are located quite close to the other existing tunnels, caverns and different kinds of sensitive installations.

"The excavation of the Follo Line tubes and the inbound Østfold Line tunnel has to be done really careful in some areas," she says. "The tunnels are crossing right under one of the main road tunnels. The distance between the top of the future railway tunnels and the bottom of the existing road tunnels is in one area at 3.5m. A river tunnel is currently located in the "spare area" between these tunnels, so this (river tunnel) has to be relocated and filled with concrete before the excavation of the railway tunnels can start in this area."

Kalager says: "In this northern part of the tunnel both the relocated inbound Østfold Line tunnel and the two new Follo Line tubes will also pass close to caverns and installations for storage and distribution of oil and petrol.

"There are strong requirements regarding the limits of vibrations for passing the main road tunnels as well as the caverns and installations for oil and petrol.

"Due to limited space for start-up of a TBM in this area, it was decided that the tunnel for the inbound Østfold Line should be excavated partly by very careful drill and blast methodology and by the use of a drill and split methodology."

Kalager explains, "TBM excavation for the two Follo Line tubes in this complex area could have been chosen as a part of using TBMs for the excavation of the rest of the tunnel, but this would have been the last part of a total TBM excavation length of more than 9km for each of the tubes and on critical path for the project. For this reason it was decided to start the excavation of all the three tunnels within this complex 1.5km-long section, early as a separate contract and to do the excavation by a combination of drill and blast and drill and blast methodology."

Above: A Herrenknecht TBM stands ready to bore the Ulriken project

As the tunnel needs to be excavated within three years, it was decided to excavate the remaining 18.5km-long tunnel section with four TBMs operating from one central access point. Drill and blast excavation was also considered, but this would have required the excavation of seven access tunnels, many of them in densely populated areas.

Two machines will start operating north toward Oslo Central station and two others will be working south, headed toward Ski. These machines will be connected to a future cut-and-cover section south of the rock tunnel.

Designed for extreme hard rock conditions, these double shield machines have a diameter of 9.96m.

Two 1km-long access tunnels have been excavated from the main rig area and down to the location for the future railway tunnels.

Additional tunnels and two large assembly chambers have been constructed using conventional drill and blast techniques.

"The cross passages between the two tubes, a total number of 44, will be also by drill and blast," Kalager says. "Precast watertight concrete elements will be installed in a closed ring to ensure rock support in addition to the prevention of water leaking into the tunnel.

" The production of these elements, roughly 141,000 segments, takes place in the main rig area at Åsland. Approximately 10 per cent of the TBM spoil will be used in the production of the concrete elements."

An EPC contract for the engineering, procurement and construction of the 18.5km-long TBM excavated tunnel section was awarded in March 2015.

The start-up of the four machines will take place during the period between September and December, and excavation should finish before the end of 2018, while the entire Follo Line is scheduled for completion in December 2021.

THE NEW ULRIKEN TUNNEL

"The section between Arna and Bergen is heavily trafficked. The current single track has insufficient capacity, and track doubling of this section will improve the situation for goods and passenger services," says Hans-Egil Larsen, head project manager.

"The biggest part of the section passes through a tunnel under Mount Ulriken. Jernbaneverket is now constructing a new, parallel tunnel in order to increase capacity.

"The double track will also permit faster speeds and improve traffic management flexibility."

Starting from the Arna side of Ulriken, the tunnel construction is excavated using both conventional blasting and a TBM. This is the first time a TBM is being used for a railway tunnel in Norway.

The first 765m of the 7.8km-long tunnel have been blasted in the conventional manner to be wide enough to accommodate extra passing tracks. That means, the cross section needs to be significantly large from 144 to 300 sqm, while it is 68 sqm in the rest of the tunnel.

Two diagonal tunnels have been blasted between the old and new tunnel, allowing trains to cross between tunnels.

Another 16 smaller cross-passages will also be blasted between the tunnels for evacuation routes and technical installations. The remaining 7km of the new tunnel will be excavated by TBM.

"There are many benefits to using a TBM rather than blasting," says Larsen. "By using this technology the project's progress can be much faster, averaging an estimated 15m per day. We can also obtain an accurate excavation profile, reducing overbreak to a minimum. We can ensure less damage to surrounding rock, reducing the need for rock support. What's more, bored tunnels generally have a longer lifespan than blasted tunnels."

This type of machine is well suited because the rock in Ulriken is mostly hard and stable. As a consequence of this, it is not necessary to stabilise the rock prior to boring, merely to stabilise with bolts, steel arches and sprayed concrete as the tunnel progresses.

The TBM is 155m-long with a total weight of 1.8t and a 9.33m diameter.

Larsen explains that the biggest challenge in the project is building close to the existing track where 120 passengers and freight trains pass every day. "Sometimes we need to stop the traffic to get the work done," he adds.

For this project the contractor is JV Skanska Strabag, which started working in August 2014, while Norsk Jernbanedrift started operating for preparatory railway's work in March. There will be a tender conference in October for the contract, which includes the Arna station and other technical works

Registration for WTC, to be held in Bergen, Norway next year, is due to open this month at: www.wtc2017.com

FIRST PLACE

China is planning more infrastructure projects, such as the Shen-Zhong Link that consists of two artificial islands, two bridges and the world's widest immersed tunnel. Michael Tonnesen, chief tunnels specialist from *Cowi*, talks to technical journalist **Rhian Owen** about the design competition process for the project and why an immersed tunnel is the right choice

Rhian Owen
Rhian began working with *Tunnels and Tunnelling* in 2011

CHINA IS CHUGGING AHEAD with large-scale construction projects, both domestic and international, that guarantee to kick-start business, bolster trade routes and safely connect people from all corners of their borders. According to the country's ministry of transport CNY 5 trillion (USD 750bn) will be spent in transport infrastructure over the next three years.

To put this into perspective, there is significantly more spending on infrastructure in China than in the US and Europe combined. According to a new study by the McKinsey Global Institute (MGI), the US and Europe saw spending fall as a share of gross domestic products (GDP) from 2008 - 2013 to 2.5 percent annually. Whereas the MGI report shows China's strength in infrastructure spending. The country spends an average of 8.6 percent of its GDP in infrastructure.

One of the country's latest projects is the Shen-Zhong Link project. The Shen-Zhong Link is a CNY 30bn (USD 4.76bn) coast-to-coast link that connects the cities of Shenzhen and Zhongshan. The project is part of a wider upgrade in and around Guangdong and the Pearl River Delta. It aims to create a more direct connection between the west and the north part of the river while reducing traffic through Guangdong.

"There's only one major crossing in the north currently in operation, close to Guangdong with a bridge across the Pearl River. There is also a crossing in the south in Hong Kong, which is around 70km away. So when this new crossing is built it will cater up to 90,000 vehicles a day. I think some 50 percent of it is heavier-than-normal vehicles. There's a lot of traffic of goods going from east to west," says Michael Tonnesen, chief tunnels specialist from Cowi.

THE COMPETITION

In 2015, the Advanced Work Office held an international design competition in which competitors were challenged to come up with a state of the art crossing for the Shen-Zhong Link Project. The engineering consulting group Cowi

An artist's concept of the completed link

All: Artist's concepts of the completed link showing bridge to tunnel interface

and the architect Dissing + Weitling, both based in Denmark, were recently announced the winner. "The competition process is often the way in China; to see if there are good ideas and development in Europe or other countries in the world that they can benefit from, and developments they haven't seen before. China is always eager to see new things being developed or practiced in the industry," says Tonnesen.

Cowi states that the key parameters for the design competition were aesthetics, functionality and price. "Key parameters were laid out, and there was a reward, so you get money to provide designs. There are times when there is not a design contract given afterwards, but maybe you get points for putting in a proposal when you've won the competition. This happens in China. In Europe this doesn't normally happen."

The design competition was a two stage approach: During stage one the key issue for the overall crossing (tunnel, islands and bridges) was architectural appearance of the overall link and to carry out an initial comparison of different options for the key elements of the crossing. This began in October 2015 and lasted until mid January 2015. "The focus here was to make the tunnels look aesthetically nice when they come out into the islands," says Tonnesen.

During stage two the focus was on the technical description and details. The recommended solution was documented through a number of analysis. "This lasted from February this year to the end of March and included the big suspension bridge, another smaller suspension bridge, two artificial islands and the immersed tunnels."

However, a Chinese designer was appointed for the actual design of the Shen-Zhong Link in April this year. While infrastructure development is a top priority for China, there are a number of challenges for foreign entities doing business in the country. One of the biggest hurdles to entering the Chinese market for engineering design, construction and consultancy is the need to obtain the requisite qualifications, which are quite stringent in the eyes of foreign companies. Another challenge for foreign companies is the need to understand the local market and the different roles of key players and stakeholders within that market. Any new business to China would be advised to partner with a local company. This is an effective way to navigate differences in the regulatory system, tax laws, contract negotiation, employment practices and corporate culture.

"The Chinese company is cracking on with the design of the tunnel and bridges at the moment," says Tonnesen. "They will go through a selection phase themselves, choosing the right solution for the tunnel. Once it has gone through the various design phases, and it has gone out for contractors to bid on - and then it has been through an adjustment afterwards to suit the means and measures of the contractor - we will be able to do an independent review and checking of all the design.

"That's what these international consultant companies were bidding for. Cowi won the bid for owners consultant together with three Chinese consultant companies: Shanghai Municipal Engineering Design Institute (Group); China Railway Tunnel Survey & Design Institute; and CCCC First Highway Consultants. So we will continue on the project during design and construction."

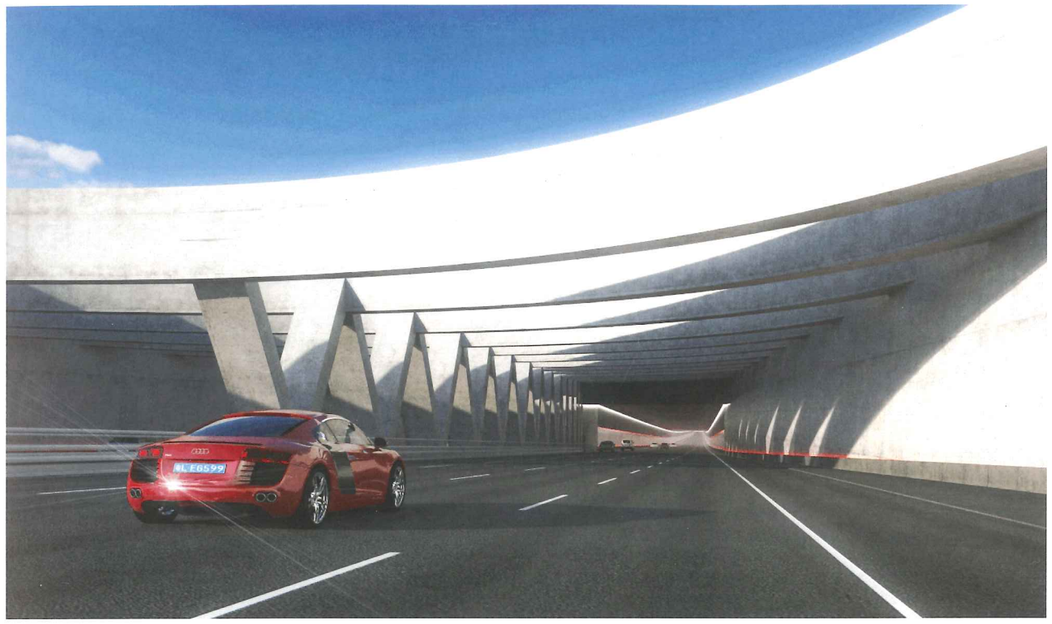
PROJECT SCOPE

The complete link will be 24km long and consist of two artificial islands, one of which will contain a 15,000 sq m conference hall as well as offices and restaurant facilities; two bridges; and the world's widest immersed tunnel with eight traffic lanes in dual directions. The proposed concept is a post-tensioned segmental tunnel consisting of 31 elements in total, a typical element being 185m long and the widest being up to 70m wide. The width of the road bore varies from 19m to 38m.

Immersed tunnels are becoming far more common in recent years, with continuous development of construction techniques and technologies that overcome challenging conditions and minimise risk. Immersed tunnels have historically been seen as a third option behind bored tunnels and bridges, but are now becoming longer, deeper and more competitive with boundary pushing projects such as the Swedish-Danish Øresund Link and the Busan-Geoje fixed link in South Korea already completed.

The decision to build an immersed tunnel rather than a bored tunnel was, Tonnesen says, driven by the desired size of the tunnel. "We will have two by four lanes corresponding to a total of eight lanes along the new crossing to cope with the predicted road traffic. The immersed tunnel was considered to be less risky and costly compared to an option with a number of bored tunnels to accommodate the eight lanes including hard shoulders.

"In addition, at the east end of the tunnel it was required to connect the tunnel with a north south running highway on a low



level bridge located in the Pearl River Delta. For the immersed tunnel this interface was easier to accommodate compared to a bored tunnel."

Immersed tunnels can be laid in poor ground conditions that would cause major risks to building bridge foundations or driving through a tunnel boring machine. However, Tonnesen says that the project still pushes the boundaries of what is technically possible.

"To minimise the water blocking and impact on current and sedimentation in the river due to the new crossing, is one of the key elements to be assessed. The Island in middle of the Pearl River, used as transition between the tunnel and the bridge part of the crossing, is one of the elements having an impact on water blockage, water current and sedimentation. The length of the island will be shorter and thereby preferred with an immersed tunnel compared to a bored tunnel," says Tonnesen. "The demand on the structural capacity to get it to work is really on the limits. We are exploring options such as steel tunnels, because the normal reinforced concrete is just on the limit of being feasible."

The tunnel will be constructed on a soft seabed requiring soil improvement to prevent the elements from settling, and in rough, open waters under deep navigation channels trafficked by the world's largest ships. In addition, the tunnel will be placed in a deep excavated trench and after it has been in use for a few decades, layers of sediment up to 20m thick will accumulate above it. The sediment combined with water pressure from above will impose enormous forces on the tunnel's central sections. "This will happen over time and we have to design for this," says Tonnesen. "Water tightness of the tunnel structure is also a key issue, as we have to address the risk of earthquakes in the region. The project bears a lot of similarities to the project we have been involved with in South Korea."

The Busan-Geoje fixed link in South Korea involved the construction of an 8.2km motorway connecting Busan, Korea's southernmost and second largest city, to the island of Geoje. It included the construction of a 4km immersed tunnel with two 170m long cut and cover sections at both ends. Similarly to what is expected on the Shen-Zhong Link project, due to soft soils the tunnel foundation included soil improvement (sand compaction piles and cement deep mixing). Towards the western landfall the tunnel elements were placed inside a sub-sea embankment above the existing seabed.

However, it's the Hong Kong-Zhuhai-Macao Link (HZM Link) project that Cowi was deeply involved in, which is currently under construction, that Tonnesen says bears even more similarities to the Shen-Zhong Link project. The HZM Link is a six-lanes highway connection crossing the Pearl River Delta between Hong Kong and the city of Zhuhai, mainland China, and Macao on the western side. The overall length of the bridge and tunnel crossing is more than 40km.

"We know how to do this type of construction in the area; we know that siltation is a key issue and sometimes during the year you get a lot of deposits from upstream up the river. We had to be mindful of this for the HZM Link, a connection crossing the Pearl River Delta between Hong Kong and the city of Zhuhai in mainland China and Macao on the western side. You have to focus on avoiding risk for the contractor later; making sure that everything is clean before putting in the foundation layer, and before you put in the tunnel elements. You will need to monitor it carefully so you don't get any delays in the construction," says Tonnesen. "But, it's difficult to really know what the Shen-Zhong Link project will end up being, as ultimately it's the Chinese companies designing it"

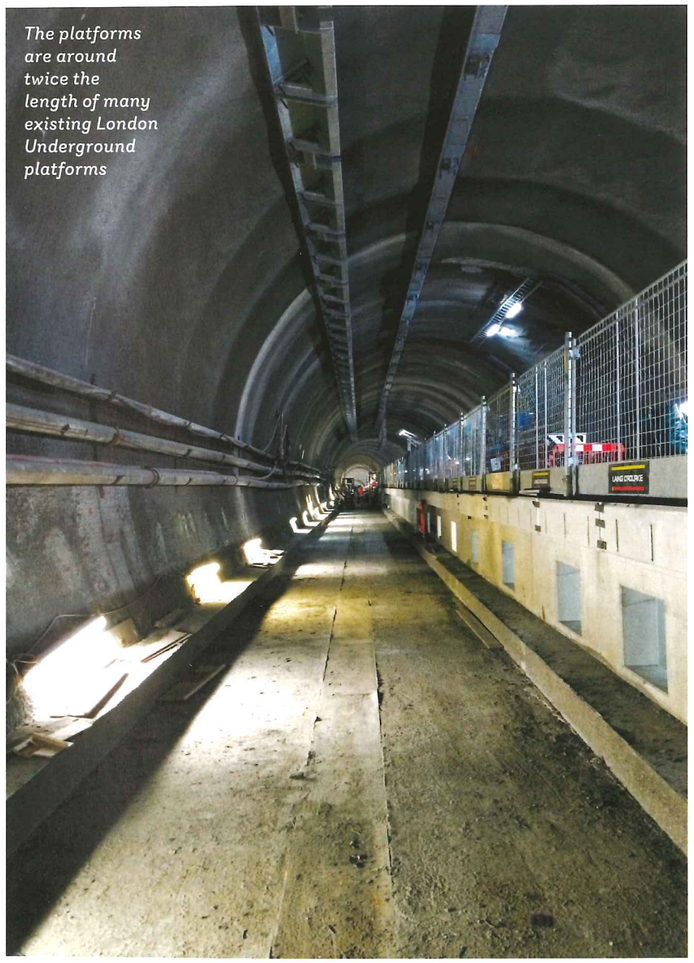
DUST BUSTER

A new real-time dust monitor being trialled at the new Liverpool Street Crossrail station could help to reduce the respiratory risks of working in a tunnel. **Keren Fallwell** reports

Keren Fallwell
Keren joined the Tunnels and Tunnelling team in 2015 as a contributing editor

ACCORDING TO BOHS, the Chartered Society for Worker Health Protection, every year in the UK about 13,000 people die from work-related diseases, and in the construction industry the incidence is particularly high.

Construction workers in the UK are 100 times more likely to die from an occupational disease than a workplace accident. This is illustrated by the fact that in 2014/15 there were 35 fatal injuries to UK construction workers whereas over the same period in the industry there were around 5,500 new occupational cancer cases, 3,500 deaths from past exposures to asbestos and 500 deaths from exposure to silica dust.



The platforms are around twice the length of many existing London Underground platforms

There are perhaps few harsher construction environments than a tunnel. Standard practice to ensure that Permitted Exposure Levels are not exceeded is for operatives to wear personal monitors but these only reveal retrospectively what the worker has been exposed to. If dust exposure levels need to be assessed the data from the monitors has to be analysed by an external laboratory and there's a lengthy wait for results.

Now British company Trolex is changing the game with a real-time respirable dust monitor – the Trolex TX8001. The company has already supplied gas monitors to Crossrail sites, where the devices are placed every 500m, and it is now trialling its new dust monitor during construction of the new Liverpool Street Crossrail station, where Laing O'Rourke has the contract for the main construction works.

The first dust monitor was installed 17 months ago in the Blomfield box, a 40m-deep shaft which will accommodate ventilation, electrical, mechanical and systems equipment for the new station.

Trolex has made changes to the monitor during the trial and there is now one in each of the two tunnels at the station. One is not fixed so it can be moved to areas where work is generating dust.

"It's done away with personal dust monitors which are used on other Crossrail sites," said Dean Bonvini, senior construction manager at Laing O'Rourke.

The robust, sealed unit provides real-time particle counting of respirable dust, which is not visible to the eye, and produces the results instantly, alerting operatives to immediate risk and negating the need for costly and time-consuming laboratory analysis. The monitor, which is linked to the site office via an ethernet cable, displays the 15-minute and eight-hour time-

Trolex's dust monitor provides real-time particle counting of respirable dust and sounds an alarm if dust exceeds permitted levels

weighted average. As it is an open flow device there is no need for filters or pumps and there are no moving parts or consumables.

"In the past we would have used personal monitors and had to have waited three weeks for the results of the readings," said Bonvini. "With this it's instant; it's a live reading."

Trolex says the TX8001 is accurate to within +/-5% compared with +/-25% for the current industry standard model.

It operates in the 1 to 10 micron respirable fraction particle range and in the event of dust concentration exceeding the upper limit, the monitor has an in-built alarm. Since it was installed at Liverpool Street, however, the alarm has never been activated.

"The results have been pretty good," said Bonvini.

Since the trial began 17 months ago Trolex has made changes to the monitor in response to Laing O'Rourke's experience with the device.

"We're on Mark III now and it will pretty much be the final spec," said Trolex business manager Mark Bennett.

The final product will be integrated with Trolex's gas monitoring systems and also include a visual indicator so site workers can easily see changes in respirable dust levels.

Bonvini said the visual display provided reassurance to operatives that they were working in a safe environment and Laing O'Rourke would be

Prefab platforms

Crossrail's Liverpool Street station will serve the City of London and provide interchanges with London Underground's Northern, Central, Metropolitan, Circle, and Hammersmith & City lines, connections to Stansted airport and National Rail services.

The station will have two ticket halls. At the eastern end a new Crossrail ticket hall is being constructed beneath Liverpool Street, while on the western side a new ticket hall be will formed by expanding the existing Moorgate station ticket hall. The two entrances will be connected by two mined platforms.

Laing O'Rourke is carrying out the main construction works, which include the 250m-long platforms in the eastern and western tunnels.

The platforms were built from more than 500 precast concrete components which were pieced together in the two tunnels. Manufactured at Laing O'Rourke's Explore Industrial Park near Worksop in the East Midlands, the concrete components were transported to site on a just-in-time basis and lowered into the tunnels down the 42m-deep Finsbury shaft, which is effectively the nerve centre for the new Liverpool Street station. A bespoke gantry crane was used for the task.

The platform slabs each weighed 10 tonnes, while the six-tonne L-shaped concrete slabs which support the platforms were also precast. Under these slabs are 12m-long prefabricated concrete boards to support the M&E services.

It took about four months to install the two 240m-long platforms, which are around twice the length of many existing London Underground platforms in order to accommodate the new 200m-long Crossrail trains. Platform construction was completed in July, meaning platforms on all central London Crossrail stations are complete, except for Whitechapel.

The glass-reinforced concrete cladding, which will be applied to the shotcrete-sprayed tunnels, will also be produced offsite.

"Using precast slabs reduced the risk and there were benefits to the programme and quality too," said Dean Bonvini, senior construction manager at Laing O'Rourke.

The Liverpool Street Crossrail station has been one of the most difficult to build in London's dense urban landscape. Obstacles that have had to be negotiated include a maze of sewers, existing London Underground lines and the Post Office Railway. In addition, the work revealed nearly 4,000 skeletons from the Bedlam burial site and thousands of artefacts dating back to Roman times. The Liverpool Street Crossrail station will open in December 2018 when the two ticket halls will provide an interchange with other lines. It will open fully in 2019 when the entire GBP 16bn (USD 20.7bn) Crossrail project is complete.

The two platforms were built from more than 500 precast concrete components

recommending the monitor's use for other Crossrail sites.

"It provides reassurance. We are always looking for new and exciting developments in the construction industry and we have confidence in it," he said.

Trolex is also pleased with the monitor's performance during the trial and Bennett believes it has huge potential, not just in the construction industry.

"I think it could very well become the industry standard for all dusty work sites, whether that's a tunnel, a sawmill or in the pharmaceuticals industry," he said

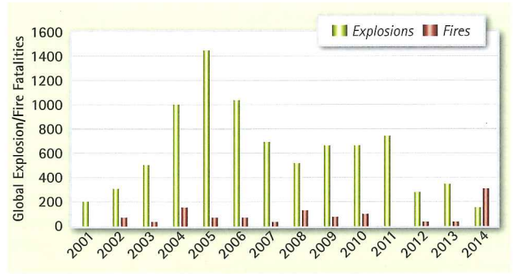
EXPLOSION PREVENTION IN COAL MINE TBM DRIFTS

Since the first record of a colliery explosion in Belgium, nearly 300 years ago, significant improvements have been achieved in the prevention of explosions in mines. However, gas explosion hazards are not unique to coal mines but also occur in TBM projects with 48 explosion fatalities recorded worldwide calling for continued diligence and improvements in explosion risk management. Success of TBMs in civil engineering infrastructure in poor ground conditions resulted in consideration of its application to a coal mine in Queensland

TBMS HAVE BEEN USED in mining related projects since the 1950s. Subsurface geological risks typically distinguish these projects from typical civil engineering applications. There have been up to 24 TBM projects in mining worldwide, viz., Canada, Zambia, South Africa, USA, Norway, Germany, Mexico, Chile, Australia, Italy, China, and PNG.

During the 1970's and '80's, Robbins TBMs were used to access coal seams in a number of coal mines globally, i.e., Selby in the UK, three mines in Germany, the Donkin Morien Mine (under sea access) in Canada and Westcliff mine in NSW (Australia). The West Cliff Colliery Men and Materials Drift had 5 m diameter and was 1595 m long. It was built in 1975/6 with an average advance rate of 27.6 m/week. Documentation of these coal mining TBM applications did not convey any known occurrence of explosion hazards during development. Other known application of TBMs in the mining industry is the 8 km long Los Sulfatos exploration tunnel of 4.5 m diameter developed for Los Bronces mine at an elevation of 4000 m. Key reasons for its selection as a development method were flexibility to access the worksite, natural restrictions related to the portal installations and geotechnical and environmental considerations. The field review showed no known experiences of any methane gas intersections during the 8km development (Belle, 2010) although a significant inflow of water had to be managed.

Success of TBM technology in establishing surface civil infrastructure and providing alternate means of rapid access in poor ground conditions, resulted in its consideration of its application at Grosvenor coal mine in QLD to establish the conveyor and men and material transport drift access roadway from the surface. The conveyor drift has a gradient of 1:6 with a length of 762 m and while the transport drift is a 993 m long and has a 1:8 gradient. Considering the geotechnical challenges, the TBM excavation method had to utilise EPB technology which is 135 m long and of 8.0 m diameter (Figure 1). For the first time, a TBM required addressing simultaneously ventilation, gas and cooling management elements,



Above: Figure 1, Global Mine Fires and Explosion Statistics (public domain sources)

and other related mining hazards. The drift ventilation and gas management systems involved the supply and control of air using an intake and exhaust airway network to manage health and safety risks.

At the time of completing this paper, the TBM had finished the conveyor drift (Figure 5) with a total of 581 rings of 1.4 m length, at a distance of 813 meters from the tunnel opening at the surface. Currently, the TBM is planned to be moved to construct the people and materials drift, involving disassembling the front section of the machine underground. The machine was then retracted out the conveyor drift using heavy lift and transport equipment and face ventilation modified to force-exhaust system to manage the Goonyella Middle (GM) seam gas emissions. This conveyor drift was completed over a period of 5 months (Dec 20th to 15th May 2014).

With the ample knowledge on methane gas and its

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Table 1. TBM encountered gases and explosion incidents worldwide

Tunnel type	Country	Year	Length, km	Diameter, m	Fatalities, #
Los Angeles Water	USA	1971	8.85	6.8	17
Oil Field	Japan	1978	UN	UN	11
Water*	Georgia	1979	UN	UN	UN
Aqueduct	UK	1985	8.5	2.4	0
Waste Water	USA	1985	34	UN	0
Water	UK	1985	UN	UN	16
EPD-TBM	Japan	1993	UN	UN	4
Mill Creek	USA	2004	4.65	7.8	0
Electric Cable	Hong Kong	2004	UN	4.5	0
Zagros	Iran	2009	26	6.73	0
Hard rock	Spain	2010	UN	UN	0

Source: Copur et al 2012
**Whole team of workers; UN-Unknown*

management in coal mines, it is a common practice in coal mines to continuously monitor and anticipate hazards that could result in explosions. Among various ventilation design factors, this paper will attempt to highlight the identification and management of methane and other gases in TBMs during drift development at Grosvenor from coal miner's perspective.

RISK ASSESSMENT

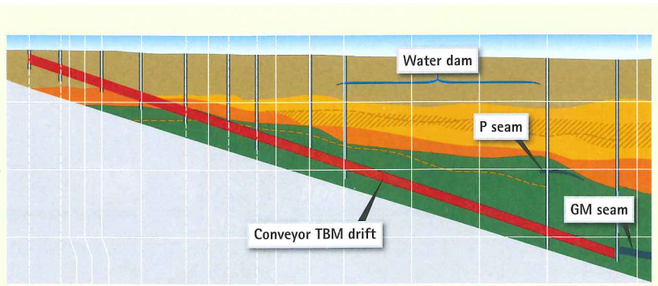
Coal mine explosion fatality statistics worldwide (Figure 1) demonstrate the need for eternal vigilance to prevent methane and coal dust explosions regardless of the level of gas emissions (Phillips, 2009). The mine explosion risks associated with TBM use was recognised by the mining team prior to start of the Grosvenor project. Copur et al., (2012) captured the gas emissions and explosion risks associated with tunnelling globally (Table 1). Based on past TBM project safety statistics which recorded 48 explosion fatalities, gas explosion hazards are not unique to coal mines.

Key lessons from the past civil TBM project experiences (Copur et al., 2002; Brox, 2013) in relation to ignition and explosion management are:

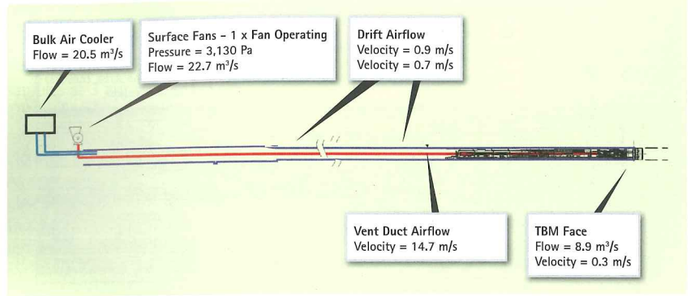
- Adequate knowledge and careful evaluations of technical and non-technical issues such as geology, access, sub-surface cover, fault zones and structures are required.
- Ensuring adequate background information on gas emissions from seams or strata for hydrocarbons.
- Need for skilled and experienced mining engineers.
- Use of gas measurement and control systems. The location and calibration of monitors at strategic locations inside TBM's cutter head, shield, and segment erector section with automatic TBM shutdown system interlock features is required.
- Ignition prevention techniques such as grouting, pre-drainage, foam injection and sealed lining during the intersection of gassy water inflow conditions should be provided.

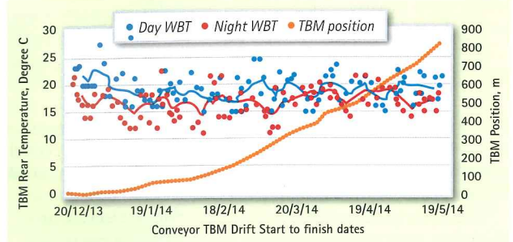
Coal Mine TBM Explosion Risk

Safety and health risk assessment is inherent to coal mining operations in Australia and is entrenched in the local mining regulations. Considering the documented explosion risks associated with TBM operations, the risk assessment for Grosvenor coal mine involved key members of the mine technical and project team, TBM operator, contractors and the Queensland regulator. The majority of risk elements identified were in relation to the use of flameproof electric motors and intrinsically safe (IS) electric components to meet the compliance requirements as per the Queensland Coal Mining Health and Safety Act (Qld CMSHA) and Regulations (Qld CMSHR), Qld code of practice for Tunnelling and also the Australian Electrical Standards. A key hazard identified during consideration of the TBM for coal mining application was the potential exposure to gasses during 10% of the tunnel length where the "P" seam coal measures would be encountered approximately 50 m above the target "GM" seam and when the TBM would be approaching the pit bottom (Figure 2) to be excavated within the GM seam horizon. This assumption was based on the information available from pre-drilled exploration boreholes. As shown in Figure 2, due to the presence of the water dam on the surface, no gas exploration holes could be drilled to a depth of between 400 m and 800 m. However, it was established that the P-seam follows over the TBM drift horizon towards the surface



*Below: **Figure 2, Geological long section profile along the conveyor TBM drift***





*Above: **Figure 3, TBM Monthly ventilation survey results (McKew, 2014).***

*Left: **Figure 4, Use of BAC at surface conveyor drift on temperature profile in the TBM tunnel***

*Below: **Figure 5, Completed conveyor drift development at Grosvenor coal mine***

with methane gas anticipated during the drift development.

The TBM risk assessment outcome ensured that the TBM incorporated relevant gas monitoring systems (shield area, cutter chamber, and screw conveyor discharge "stuffing box" assembly area) with automatic shutdown interlock feature should methane detected in any of these TBM sections. In addition, these measures incorporated the NERZ/ERZ requirements as legislated in the QLD Coal Mine Safety and Health Act (CMSHA) and Regulations (CMSHR, 2001).

TBM VENTILATION AND COOLING SYSTEM

Unlike the traditional continuous miner or road header machines in a coal face, the TBM face area at the front of the machine is sealed and potentially could contain a gas mix that may be liberated from the face area in the sealed chamber area. The EPB chamber and screw conveyor section are pressurised during excavation activities. The TBM exhaust ventilation design consisted of 2.0 m diameter steel duct continuously advanced using automated controls behind the TBM. The ducting was connected to a 150 kW surface centrifugal fan. The fan would induce adequate air flow to the face and tunnel. The exhaust ventilation system included a methane sensor to monitor the gas levels as in a typical mine shaft system. The steel duct was connected to a ribbed flexible ducting section to maintain a maximum draw-off distance of 2.0 m from the face during the cutting cycle. The ducting was positioned in such a way that any gas present near the screw conveyor or inbye the TBM area would be removed continuously from the face area. Figure 3 shows the typical ventilation circuit and the pressure-quantity survey results to be in compliance with the Qld CMH and S regulations, S342-S365 (McKew, 2014).

Figure 4 shows the TBM roadway temperature profile at the rear of the TBM area (behind the gantry 9 of the TBM, i.e., 100 m from the face). One of the observations made from the measured data is that there is a consistent Wet Bulb Temperature (WBT) difference between day and night. It is also noticed that the measured WBT during night shift is higher than the day shift WBT. This implies some type of data inaccuracy and points to the need for other, unbiased continuous real-time velocity and temperature monitors for underground use (Belle, 2014).

In addition to TBM heat load, steep geothermal gradient and very high surface ambient air temperatures (24°C WBT and 35°C DBT) in the Bowen Basin (Belle and Biffi, 2013) required the need for supplying cooled air during the TBM development to manage the thermal stress. This was achieved by a mobile surface Bulk Air Cooler (BAC) ducting at the drift entrance with a capacity of 15 to 20m³/s of cooled air supplied at 10°C (Figure 5).

RISK CONTROL EXPERIENCE

In 2001, the Queensland legislation formalised the need for Explosion Risk Zones (ERZ) in underground mines that would allow for greater flexibility and continuous methane monitoring with alarms and relevant electrical power trip interlocks with the equipment. Section 286 requires the Site Senior Executive (SSE) to ensure that a risk assessment is carried out to identify the location and type of each ERZ at the mine. The zoning is risk based considering mining activities, absolute levels of methane in the general body (GB) and including foreseeable events and failure modes. The risk zones may be classified as one of ERZ0, ERZ1 and Negligible Explosion Risk Zone (NERZ). Section 287 of the Qld regulation defines ERZ0 as an underground mine, or any part of it, where the general body concentration of methane is known to be, or as identified by a risk assessment is likely to be, greater than 2%. To avoid any doubt, it is declared that, if the general body concentration of methane in a part of the mine that is defined as ERZ1 or NERZ becomes greater than 2%, then that part becomes an ERZ0.

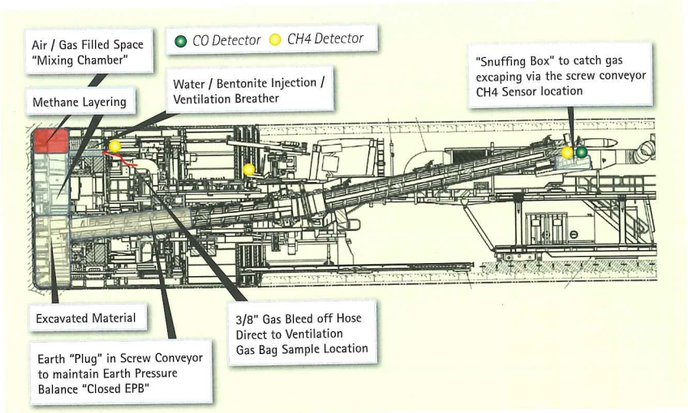
Section 288(1) of the Queensland regulation defines ERZ1 as an underground mine, or any part of it, where the general body concentration of methane is known to range, or is shown by a risk assessment as likely to range, from 0.5% to 2%. In addition, Section 288 (2) defines each of the following places is an ERZ1-

A. A workplace where coal or other material is being mined, other than by brushing in an outbye location;

B. A place where the ventilation does not meet the requirements for ventilation mentioned in section 343 or 344;
C. A place where connections, or repairs, to a methane drainage pipeline are being carried out;
D. A place where holes are being drilled underground in the coal seam or adjacent strata for exploration or seam drainage;
E. A place, in a panel, other than a longwall panel that is being extracted, inbye the panel's last completed cut-through;
F. A goaf area;
G. Each place on the return air side of a place mentioned in paragraphs (a) to (f), unless the place is an ERZ0 under section 287;
H. The part of a single entry drive with exhaust ventilation inbye the last fixed ventilation ducting in the drive.

Section 289(1) of the Queensland regulation defines negligible explosion risk zone (NERZ) as an underground mine, or any part of it, where the general body concentration of methane is known to be, or is identified by a risk assessment as likely to be, less than 0.5%. As in all coal mines, the TBM work area requires explosion risk zoning (ERZ) and is shown below in Figures 1 and 7.

The principal method of gas control from rib emissions during TBM development is the continued application of precast concrete linings installed around the excavation's perimeter within the shield (but behind the bulk-head) as the TBM advances. Another gas control measure was provided by the use of the auxiliary face ventilation described above. The concrete lining is fully grouted as the shield advances, sealing the perimeter of the excavation from gas or water ingress. The section between the bulk-head and cutting face [cutting chamber] typically is an area where gas liberated from the surrounding strata is expected to be present. During EPB controlled development, the TBM machine is operated in "closed" mode where the TBM face area is sealed from the general tunnel environment with steel brushes packed with fibrous grease and



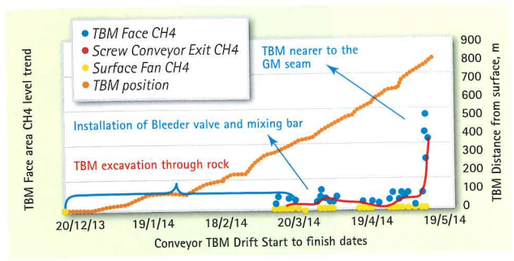
Above: ***Figure 6, Gas monitoring stations on the TBM face area***

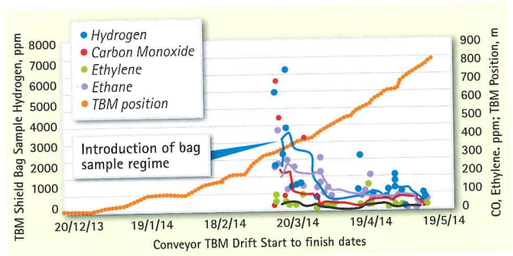
Below, left: ***Figure 7, Measured methane levels in bag samples from the TBM shield area***

Below, right: ***Figure 8, Measured sponcom indicator gases in bag samples from the TBM shield area***

pressurised with a combination of foaming agents, drilling muds and water. Closed mode operation is principally designed to control ground pressure acting to collapse the side walls of the excavation but also isolates any resultant gas from the general body.

One of the positive attributes of coal mining and welfare of its workers is the constant vigilance in identifying the health and safety hazards through continuous and regular monitoring and inspections. There were a number of operational experiences related to identifying the methane hazard and its management that were previously not well understood or documented in the TBM applications in civil or mining projects. The gas monitoring system that was implemented while the TBM was cutting the stone strata was complemented with deputy's hand held multi-gas detectors, a regular bag sample regime and the real-time gas sensors present at the face area and at the screw conveyor duct exit. The Carbon Monoxide (CO) limit at conveyor was set at 10 ppm alarm and 30 ppm power trip. As is normally done in coal mines, bag samples collected from the TBM area were analysed using the Gas Chromatograph (GC) at a nearby operating coal mine. The early bag sample results from TBM samples showed that hydrogen was generally present in concentrations around 1,000 ppm, even when CO and ethylene were negligible. Based on coal mining experience, there was no reason for concern initially since the regular presence of hydrogen; CO and ethylene indicate any spontaneous combustion of carbonaceous material in the strata. As part of the routine bag sampling and analyses (11th March 2014), elevated levels of CO, CO_2, hydrogen, and ethylene in abnormal proportions were encountered while the TBM was cutting in the stone zone (~ 300 m from the surface). Initially, the measured gas levels were reasoned to result from the presence of a range of greases used to positively pressurise the cutter bearings of the TBM. The bag samples collected at the face area and screw conveyor indicated that CH4 was found in the face area (< 2 %) and very low levels of methane (~0.1%) were detected where face/muck removal by the screw conveyor at the snuffing box. Similarly, the levels measured





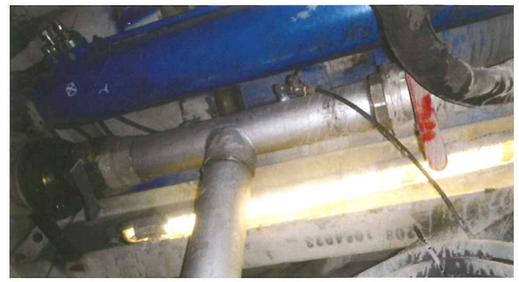
at the exhaust fan on the surface were ~0.1 % to 0.16% in 25 m^3/s of air (i.e., 40 l/s of methane). In order to better understand the phenomena, a bag sample strategy was implemented to collect samples at 3 am and 3 pm each day with results in relation to the TBM advance rate and its location shown in Figures 8 and 9.

An immediate investigation was initiated upon detecting elevated levels of methane and other gases from bag samples. As part of the investigation, the TBM was stopped for visual observations the shield face area. Seized cutter head discs were found contributing to heat generation and resulting in increased temperature that resulted in additional grease usage.

Based on the gas detection and elimination process, it was concluded that there are two separate and distinct gas sources occurring at the TBM face area, i.e., methane release from carbonaceous rocks and other hydrocarbons suspected to be emanating from hydrocarbon based chemicals used in the rock cutting and support process in the TBM face area enclosure.

With the introduction of the bag sample regime data and field observations, the following methane and hydrocarbon management controls were attempted:

- A mixing bar was fitted to the cutter head to create a turbulent airflow within the cutter chamber to assist in gas mixing and prompt dilution and to prevent regrinding in order to reduce the heat and production of hydrocarbons. In order to manage the risk at the enclosed face where a possible layer of methane (< 2%) may be present, positive ventilation was seen as a control. However, the application of positive ventilation of the cutter head was not possible due to the sealed enclosure head and other operational risk assessment outcomes. A sample hose at the bulk head area was introduced to bleed air in an attempt to reduce the methane layering.
- In order to eliminate the presence of voids inside the TBM's pressurised cutting chamber, the quantity of the injected bentonite and foam mixture was increased. This control resulted in increased muck temperature. Alternatively, bentonite use was reduced and foam quantity was increased to reduce the operating temperature (Figure 11). At this stage, it was noted that the cutting strata was a mixture of hard and soft layers interspersed with carbonaceous pockets.
- Considering the presence of other hydrocarbons, the thrust pressure and cutting rate were reduced to minimise the muck operating temperature in conjunction with the introduction of a muck heat Trigger Action Response Plan (TARP) with additional foam/fluid mix. Reduced thrust pressure of the EPB-TBM and implementation of muck heat TARP to 45°C further reduced the generation of hydrocarbon products.
- Lastly, as used in coal mine spontaneous combustion management and goaf seal management, continuous low temperature enabled Floxal nitrogen to be introduced, instead of compressed air for the generation of foam designed to minimise void creation. This resulted in the generation of an inert atmosphere in the face area and reduced heat generation that otherwise would have stimulated hydrocarbon generation.



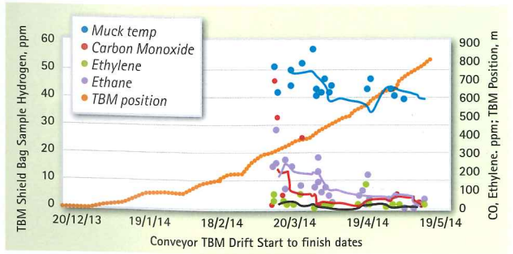
Top: ***Figure 9, Typical coal lenses***

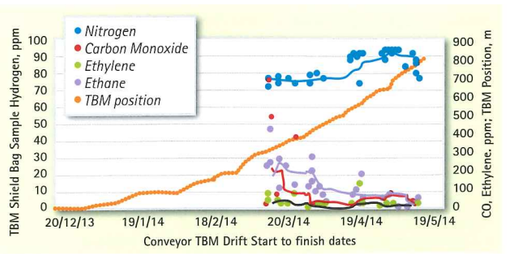
Above: ***Figure 10, Methane sampling/ bleeding hose***

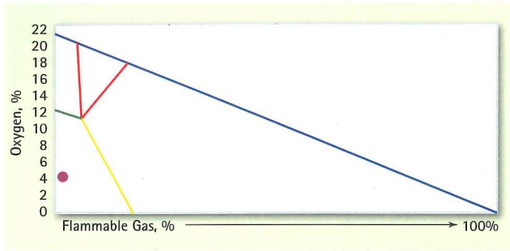
Below, left: ***Figure 11, Influence of muck temperature and nitrogen injection to TBM shield area***

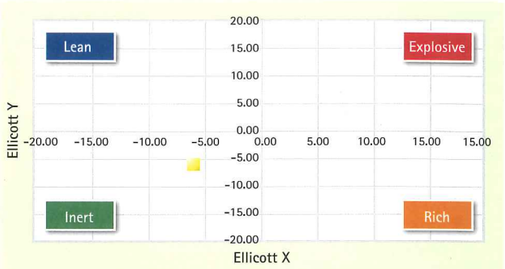
Below, right: ***Figure 12, Influence of Floxal nitrogen to TBM shield area to create inert atmosphere***

Figures 13 and 14 shows the influence of injecting of nitrogen through the existing in-situ Bentonite line directly into the cutter chamber to create an inert atmosphere. Purging of the cutter chamber was introduced after cutter inspections to ensure an inert atmosphere is provided prior to rotating the cutter head. After the introduction of nitrogen, the methane gas from the carbonaceous material present in the EPBM face area behaved as an inert blend as opposed to an explosive one. This resulted in a decrease in the magnitude of hazardous gas spikes without affecting the generation of the spontaneous combustion indicator gases. It was speculated that the methane is most likely to have come from strata, although coal seam was not intersected. Other benefits of injecting nitrogen gas at low temperature was the reduction of the overall muck temperatures to below 45°C which otherwise would have resulted in more carbon monoxide being generated and other chemical odours being detected. In summary, based on the results, it was noted that the likely source of carbon monoxide and ethylene is different from that producing hydrogen.









*Above: **Figure 13, Coward triangle and Ellicott's diagram indicating TBM face inert atmosphere***

The presence of high levels of hydrogen identified initially at the start of the drift could not be explained.

As noted from Figure 7, when the TBM approached the GM seam, the gas levels at the face area increased due to the formation of a gas sink. In addition, with the retraction of the TBM face area, and due to the buoyancy effect of the gas in the TBM decline, the ventilation had to be altered with a force ducting to provide adequate dilution and eliminate the formation of explosive gas mixtures. Although high gas levels were observed at the EPBM chamber, the highest measured gas level from the surface fan was 0.11% of methane. While there may be multitudes of ratios that would indicate coal heating, a simple CO/O2 deficiency ratio of < 0.01 of the bag sample results disproved any existence or initiation of coal heating contributing to measured sponcom indicator gases.

TBM FLUIDS FOR METHANE SOURCES

Based on the measured gas levels obtained from the bag samples taken at the TBM face area, it was decided to identify through laboratory means, whether hydrogen, ethylene, carbon monoxide, ethane and methane are liberated from the heating of chemical fluids used in the operation of the EPB-TBM. Furthermore, after the implementation of nitrogen inertisation as part of the explosion risk management process, laboratory testing was carried out to distinguish between oxidation and thermal degradation of products used in the TBM. The five samples submitted for testing were; foam, polymer foam additive, grease, sealed bearing oil and wear indicator oil. Laboratory testing on the five samples was conducted at SIMTARS by heating each of the samples (except foam) incrementally up to at least 250°C in both nitrogen and normal air flow (Brady, 2014). Out of the five samples tested the most likely product contributing to the elevated hydrogen is the foam. Although not as high as those measured in samples collected from the TBM similar concentrations were measured in samples from both nitrogen and air tests up to ~150°C. Most of the other products tested would produce carbon monoxide and ethylene if heated above 200°C accounting for spikes of these components at various times. Figure 14a to 15e show the generated gas level data from chemical products used in TBM shield area along with the spontaneous combustion indicator gases of four Grosvenor coal samples (i.e., carbon monoxide, hydrogen, ethylene, methane and ethane). The results indicate that at the various temperature conditions of the muck in the TBM face area, the measured gas levels in the face area of the TBM are not as the result of spontaneous combustion activity of any carbonaceous strata material.

Similarly, from the laboratory test results of heating individual chemical components used in the TBM, it was concluded that it is unlikely the methane measured in the TBM samples came from any of the products analysed. The measured value of 0.27% in grease appears to be an anomaly, as it was the only measured methane at various temperature conditions (Figure 14d). The laboratory test results of generated gases have indicated that hydrogen; ethylene, carbon monoxide and ethane gases are generated even while being purged with nitrogen with noticeable odours generated when heated above 200°C. These odours were noticed by the TBM operators during the TBM conveyor drift development. Amongst the five chemicals tested, the grease was found to be the primary contributor towards the significant volumes of hydrogen, ethylene, and CO at higher temperatures. However, it is important to note that any interaction effects of these chemicals that may have resulted in the generation of methane or other gases was not studied and cannot be discounted at this stage. Amongst the other gases recorded, the reasons behind the significantly higher measured levels of hydrogen prior to nitrogen injection and temperature control of the muck in the

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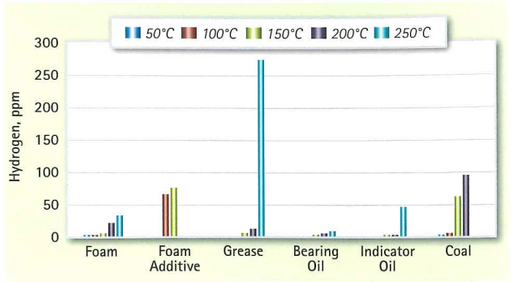
TBM face area were not clear. Therefore, it has been planned to introduce the bag sample regime from the beginning of the men and material drift development. While continuous nitrogen injection has definitely assisted the temperature control and maintaining inert mixture of the explosive gas (Figure 13), it had minimised the chance of methane ignition in the face.

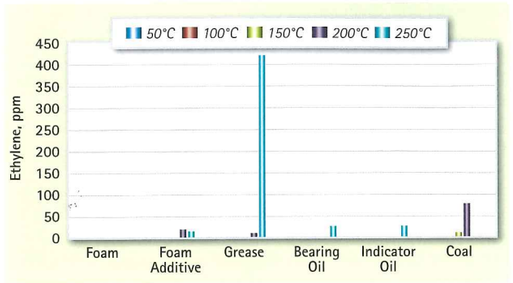
CONCLUSIONS

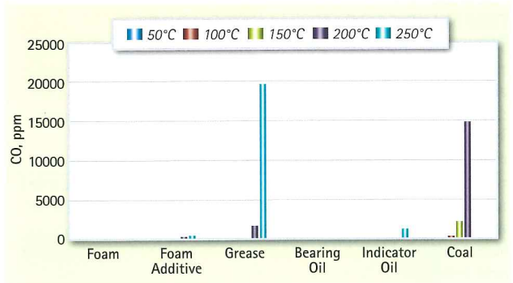
The application of the EPBM in the development of the conveyor drift (813m in length) was safely completed with success with significant learnings in the methane and other hazardous gas identification and its effective methane explosion risk management. At the time of completion of this paper, the men and material drift development using the same TBM has been initiated. The following conclusions applicable to a coal mine or other civil TBM projects in managing the explosion risks were made:

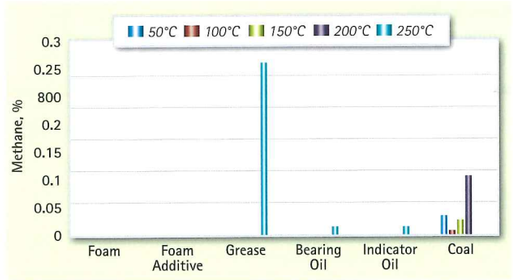
- For the first time in the application of TBM development in coal mines, the operational experience has suggested that methane and other spontaneous combustion gases will continue to be present as potential explosion hazards.
- The chemicals used in the muck management and stability of the EPBM face area may also generate levels of spontaneous combustion indicator gases at elevated muck temperatures suggesting that maintaining a low muck temperature would be beneficial in managing harmful gas generation.
- Application of continuous nitrogen inertisation as spontaneous combustion and explosion management was successful in managing the explosive gases present at the EPBM face area.
- Continuous monitoring and maintaining a well-established gas bag sample regime and controls including the TARPs for various gases and ventilation controls must be continued in managing potential explosion risks.
- Considering the recorded 48 fatalities in the last 45 years due to gas explosions in the tunnelling industry, civil engineering tunnelling projects must apply Qld NERZ/ER1/ERZ0 explosion risk zoning; hazard monitoring practices using continuous monitoring systems; bag sample regime and the use of TARPs for risk management, and the use of nitrogen inertisation to maintain inert atmosphere in the TBM face area.
- Ensuring relevant operator skills with adequate coal mine ventilation, gas and heat management experience is valuable for the industry in eliminating explosion risks from future TBM projects

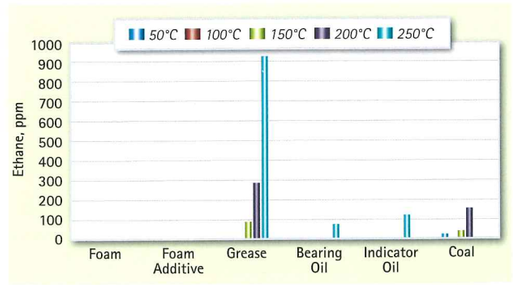
Right: Figure 14, Comparison of generation of gases from chemicals used in TBM face area- Hydrogen (top 14a), Ethylene (next 14b), CO (middle 15c), methane (below middle 15d) and ethane (bottom 14e) at various temperatures











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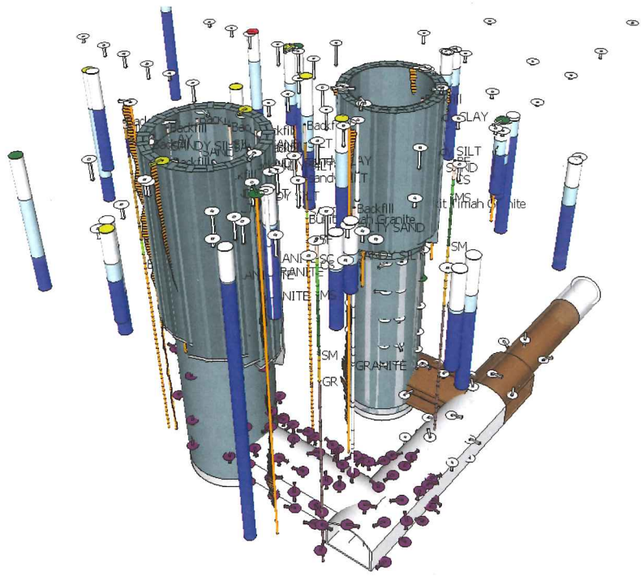
MONITORING TEMPORARY WORKS IN TUNNELS

The March presentation to the *British Tunnelling Society* describes the application of 'cloud based data' to real time review of temporary works performance against design within tunnels, illustrated by a number of example projects in the UK and Hong Kong. Presenters were **Angus Maxwell**, chief executive of *Maxwell Geosystems* and **Marcos Invernici**, standing in for **Anmol Bedi**, both of *Bedi Consulting*

Angus Maxwell
Angus is chief executive at Maxwell Geosystems, a geotechnical data analyst

Anmol Bedi
Anmol is the director of Bedi Consulting a specialist geotechnical tunnel consultant

IN RECENT YEARS TUNNEL PROJECTS have stated to collect lots of data. The objective behind the data is to achieve greater certainty in construction and, if the processes work effectively, the data can reduce risk and accelerate the works. If the processes are not effective then the data can become an impediment to the works and can increase uncertainty and reduce confidence. To ensure the former systems need to address some of the common issues surrounding data and information, key among them being the tendency for people to operate in silos. The presentation focussed on some new developments in this area and was illustrated by reference to projects in the UK and Asia.



*Below: **BIM output for Singapore Cable Tunnel shaft sites***

DATA SYSTEMS AS PART OF PARTNERING ARRANGEMENTS

Adversarial contract terms are not a good starting point for data collaboration but on the 39 km Singapore Power cable tunnels the client took an unusual approach during the tender process requiring the contractors to invest and partner in information sharing at the highest level.

The tunnels were driven using 14 TBM Tunnels in Granite rock, mixed face with decomposed soils, meta-sedimentary strata and old alluvium from 19 shafts. They were divided into NS and EW systems with 3 main contracts in each. Geology varied from highly fractured water bearing meta-sedimentary rocks of the Jurong Formation into Bukit Timah Granite with corestones at rock head, deep weathering layers with overlying fill and peat in places to Old Alluvium with loose fluvial sands and marine muds above in the east.

The tunnels were driven from 18 no. approximately 20m diameter shafts up to 60m deep and constructed using diaphragm walls in 12 panels 3 bites. The bases of the shafts were extended by drill and blast into rock with adits

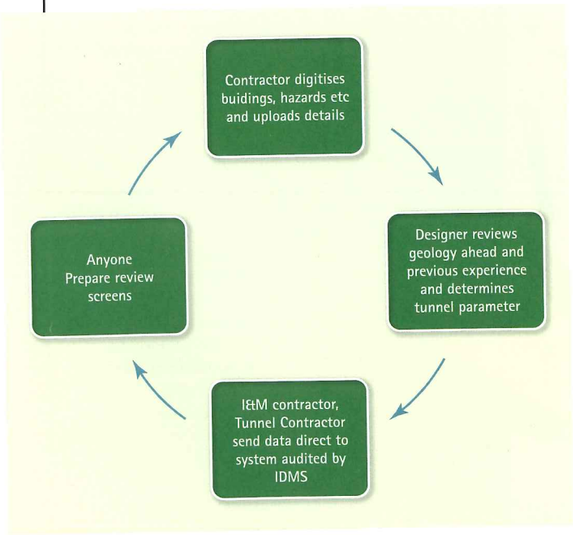
Table 1

Data Type	Digital form	Submitted by:	Alternative
Programme	CSV export from project planners	FTP/Direct upload	
Setting out	XYZ in CSV	FTP	
Progress of the works	List in CSV	FTP/Direct upload/Email	
Boreholes	AGS format files	FTP/Direct upload	PDFs linked to BH instrument
Instrumentation	Xls, csv, ODBC sources	FTP/Direct upload	
Predictions (tunnel)	List in CSV	FTP/Direct upload/Email	
Predictions CSV	CSV	FTP/Direct upload	
Hazards	Digitised xyz	Direct input	Paper (PDF) and digital reports
Sensitive structures	Digitised xyz	Direct input	Paper (PDF) and digital reports
Site photos, documents	Attached to pins or objects	Direct upload	
Activities, Labour, Plant, Materials	Direct entry	Direct input, from TBM data, from excel files	Paper (PDF) and digital reports
Site data (eg drilling, support, mapping etc etc)	Direct entry or files eg for laser scanning, measure while drilling	Direct entry or direct upload	Paper (PDF) and digital reports

Source: Authors

and enlargements. The main drives were driven by TBMs with slurry machines used in rock/mixed face conditions and EPBMs in Old Alluvium. The permanent lining was constructed with 1m and 1.4m rings to allow tight radii to follow road alignments. This required careful segment reinforcement design.

An earlier phase 1 had been difficult with stoppages due to settlement. The Phase 2 tunnels posed many risks including sensitive structures and compressible soils. With the tunnels being deep there was a need for hyperbaric interventions to control inflow. Many of these would be in mixed geology and mixed face including many rock head transitions which had proven to be difficult in previous tunnels. The tunnels were also driven in close proximity to a variety of sensitive assets and the client needed something to increase confidence.



*Below: **Figure 2, Tunnel design review process***

THE IDMS CONSULTANT

Singapore Power and their consultants decided to include information as part of the project partnering and risk sharing arrangement. A contract was prepared to select an agency to install and maintain a system for the whole project. The system took monitoring from others and independently processed information and undertook audits. All Client and Contractor parties contributed to the cost and ALL project data was loaded. It was mandated at project director level and the IDMS must be used at all meetings involving the client, consultant and contractors.

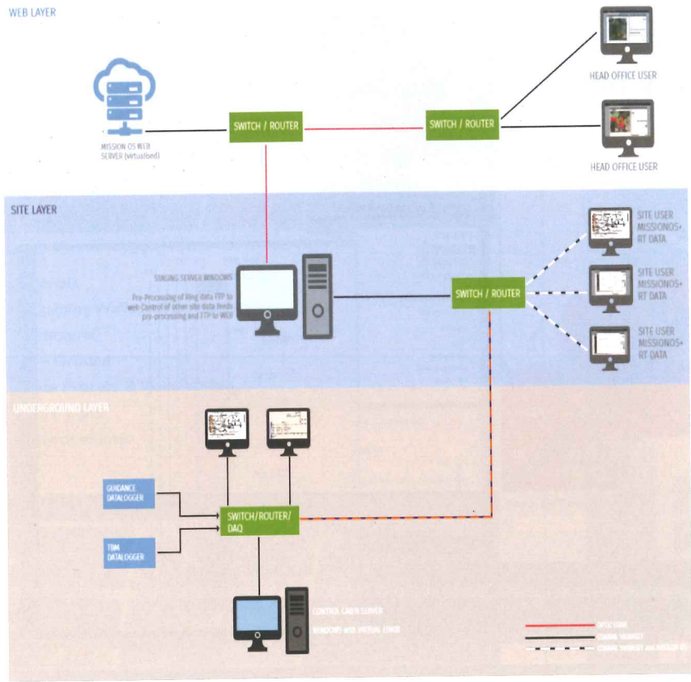
The platform ultimately contained 42,000 instruments, >20 million data records, data from 20,000 rings with up to 1,300 parameters recorded at three-second intervals. The accumulated databases were many tens of Gigabits in size. Data volumes of this size were clearly impossible to be handled in spreadsheet format and the MissionOS Platform using MySQL databases facilitated data handling and enabled rapid real time feedback on the works for decision making.

TARGETED PROCESSES

Rather than simply being a repository for TBM data the system targeted common site processes aiming to make these more efficient and effective. A key requirement of all tunnel jobs is the daily TBM tunnel review meeting, where hazards and risks and forecasts of geological conditions are reviewed in parallel with the condition of surrounding monitored sensitive infrastructure. The performance of the TBM within the preceding ground was reviewed and decisions were made as to the appropriate TBM target parameters.

SYSTEM DESIGN: AN OPERATING SYSTEM FOR DATA NOT A BLACK BOX

Key to this process was the reliable real time collation of a wide variety of data from tunnel surface and web layers with built in redundancy which allowed critical processes to continue if tunnel to surface or surface to web connections were compromised. In this way each site compute ran a virtual Linux machine and operated as a web server. Data provided at web level, surface level and TBM level was combined for full real time display. Each



*Above: **Figure 3, MissionOS system schematic***

layer maintained a cache of data from each other layer such that if there was a loss of connectivity the ability to function was maintained.

In order to get greatest benefit from the combined talents of the site team data systems needed to enable engineers to dig into the data, identify trends and relationships and express themselves by building useful reports and views which guided the risk management and design forecast process. Care was taken to allow a high degree of interactivity and customisation of the way data was combined and viewed.

LINKING DATA FOR DISPLAY AND CALCULATION

A key requirement for the systems was for them to provide linkage between cause and effect as well as prediction and performance. To understand the context of the predictions there was also a need to link data to ground conditions both factual (borehole tests etc.) and interpreted (sections, maps etc.) The systems were able to connect data spatially (i.e. in terms of coordinates) but also against the project chainages for various elements. To do this the setting out of each main element of the works must be defined and completion targets set. Against these spatial definitions the system hung prediction information in advance of the works.

Linking these data enabled the users to look at information in a new informative way. Review levels were set as proportions of design predictions and data presented to reflect design sections and sequences. Second order parameters were also be defined and calculated. This can be a simple combination of two settlement points to determine tilt or a combination of data to define key structural parameters for a building.

CANVAS REPORTS: CUSTOMISABLE REPORTING AND ANALYSIS TO FACILITATE ENGINEER'S ANALYTICAL EXPRESSION

Freed from the need for data manipulation in spreadsheet and word processor, engineers can stat to create comparative sheets to identify trends in the data and assist communication and forward forecasting. This is achieved using innovative 'canvas' screens which enable an infinite number of plot combinations to be designed. The canvas screens do away with the need for laborious preparatory work ahead of tunnel review meetings with complex screens automatically updated with the latest data for discussion. Staff members were also able to query the data and do very quickly analysis on the fly during the meeting using the MissionOS. The end result was discussion on the trends and relationships shown in all the data, not on cherry picked subsets, which support a particular conclusion. This resulted in shorter focussed meetings with better informed staff and reduced project risk.

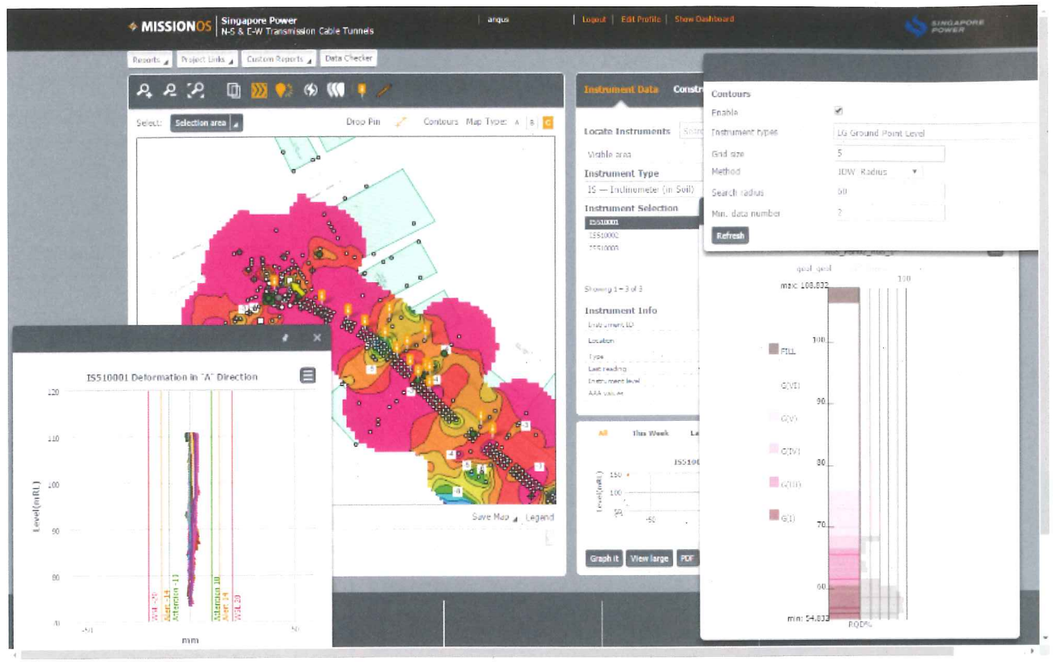
FACILITATING THE FEEDBACK PROCESS; ROCKHEAD TRANSITIONS

The N-S tunnels were driven at around 60m depth and were expected to encounter several rock head transitions. Risks included the inaccurate prediction of the transition from available boreholes leading to the need for interventions in mixed face conditions and subsequent water inflow. With variable weathering and fractured zones at the margin, loss of slurry and resulting face pressure drops may result in settlements. Review of initial transitions showed that mixed face conditions were encountered at locations different to those depicted on the contractors initial design sections. Using this feedback the contractor's increased face pressure well in advance of the transition and set a higher minimum pressure on the TBM. Interventions were carried out earlier to ensure that these were not carried out within the fractured and porous transition zone. Bulking factors were adjusted as soon as face pressures showed loss of pressure indicating the transition from full face rock. The resulting settlements were controlled effectively and improved as the job progressed.

It should be noted that these screens were also available to the machine operator underground and can be updated continuously with new borehole information throughout the course of the job. Each screen is interactive so that upcoming boreholes can be interrogated.

CONTROL OF FACE PRESSURES AND MUCK BALANCE

Machines may have anywhere from 3 to more than 10 pressure sensors on the face and conventionally these are

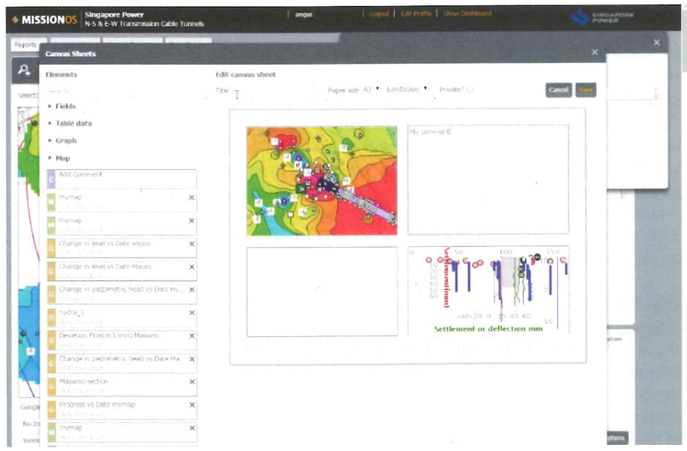


displayed as a series of line graphs. Since there is considerable pulsing of the overall face pressures during the mining process these are difficult to interpret. However, plotting these as face pressure distributions provides a much better insight into the normal conditions and aid recognition of exceptions which may occur due to slurry loss, change in EPBM muck condition or a malfunctioning sensor.

Similarly the muck balance is an extremely difficult parameter to measure and control. Putting the data together on one set of screens enables the user to see geology, settlement and design target volumes and see the grout volumes inject in their correct positions. Such rapid assimilation and presentation enables TBM engineers to react to over-excavation by increasing grouting pressures and volumes in appropriate places to deal with loosening before it has migrated to the surface.

ALARM RESPONSE AND FEEDBACK - THE KUALA LUMPUR MTR EXPERIENCE

The Kuala Lumpur (KVMRT) metro required the construction of 12km of twin tube tunnel through karstic limestone and sandstones/siltstones of the Kenny Hill Formation. These were arranged in stacked and side by side with a transition in between. The overlying deposits were highly variable and compressible. To mitigate the risk of



*Top: **Figure 4, Multi-level display***

*Above: **Figure 5, Canvas display***

ground and structure movement the consultant set out a nine point plan for managing alarms on the Job. This required all members of the contractor's team to contribute to the process within a defined period of time. With more than 2,500 alarms this process became a significant challenge and the contractor sought ways in which this could be optimised.

The Mission OS alarms and alerts were sent via SMS and email as standard and to this we added the option to send data to weblogs which acted as an on-line in-message board to manage the responses. Behind this, logic was added to allow the definition of groups of users responsible for particular actions and the system set up to control and close out the process. This worked exceptionally well and built on site staff's familiarity with the social media platforms. As a consequence the system became a truly active risk management tool capable of turning round live reports within a matter of one or two days rather than weeks as

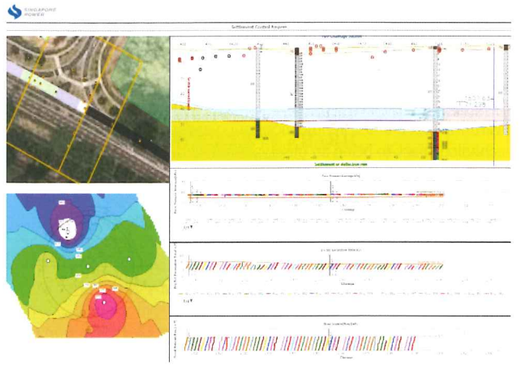
had been the case. Each report was now just the end product of a thread of observations and responses which was tracked through to completion of the job.

OBSERVATIONAL ENGINEERING ON THE LIANTANG – HEUNG YUEN WAI BOUNDARY CROSSING

The Liantang Heung Yuen Wai boundary crossing comprised some 5 km of tunnels driven at large, > 14m diameter, using a combination of drill and blast, mined and TBM tunnels through hard rock and residual soils in Hong Kong. A full description of the project was outside the scope of the presentation but rather it focused on the observational engineering undertaken by the contractor at the north portal in order to mine an initial curved section at a diameter of 20m. The objective of the approach was to address design uncertainties as to the performance of the residual soils and transitional (rock soil) materials and to establish whether steel invert struts could be dispensed with saving time and money.

COMPLEX PORTAL CONSTRUCTION IN DIFFICULT GROUND

The 20m wide mined tunnel spans were constructed by heading and bench. Strain gauges were installed on steel members in sidewall and crown positions to monitor total load and the bending generated in the support beams as the bench and then the adjacent tunnel were excavated. Strain gauges were also installed in 9 locations along 7 rows of anchors drilled



Above: Figure 6, The software facilitates data handling

Left: Figure 7, Settlement control on the Singapore Cable Tunnels project

45m into ground to tie back a 22m high bored pile wall. Deflection was measured using inclinometers, 3D prisms and extensometers. The Mission 05 system was instrumental in enabling the comparison of data in real time and resulted in rapid agreement of performance and modification of design.

ISEGMENT – WIRELESS MONITORING OF TEMPORARY LOADS DURING ERECTION

In addition to the portal construction the contractor needed to be innovative in his approach to the TBM tunnel since this would need to be broken out and enlarged from 14m to 20m for line of sight requirements. The contractor proposed the use of fibre reinforced segments over conventional reinforcement since these would be significantly cheaper and easier to break out. The concern was that these segments might not be suitable for the final lining since construction loads from the thrust rams were expected to be high resulting in cracking under high shear forces around the rams and between adjacent segments. A minimal conventional reinforcement was designed to cope with contact loads and the remaining reinforcement was provided by fibres.

A novel approach to instrumentation of the segments was designed to capture fully the dynamic loads during the construction process. No external cabling was allowed and, to manage power consumption, vibrating wire gauges were not considered. Laboratory foil type gauges were used instead. These were mounted on elastically transparent fibreglass frames and linked to signal conditioning and analogue-to-digital conversion modules (SGM) which were placed inside the concrete. The SGM cabling could be reduced to a single digital data bus (RS485) and directed to a small data logger which can record for long periods using conventional D cells.

Battery life was dependent on polling frequency temperature and other ambient

conditions. Initially data was polled every minute and up to 10 seconds during key periods.

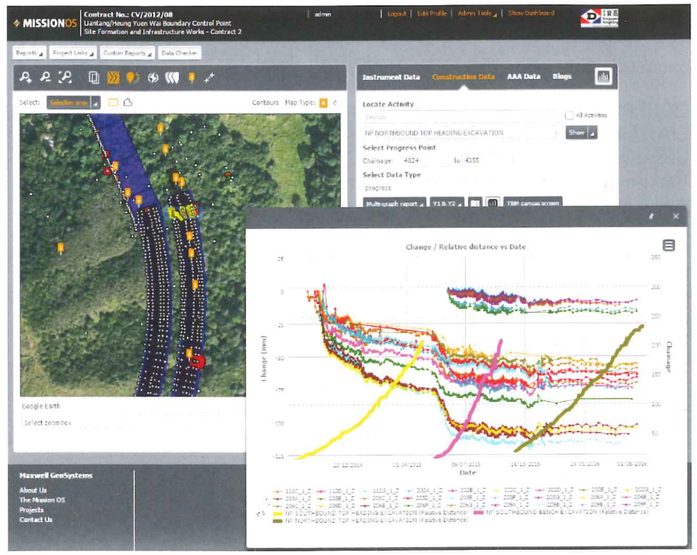
AUTOMATED DESIGN FEEDBACK ON VICTORIA STATION UPGRADE

The application of automated design feedback was trialled as a pilot at Victoria station upgrades in London. Here shaft excavations for step free access were made within 300 mm of existing operating tunnels.

The SGI cast iron linings with simple knuckle joints are highly sensitive to lateral displacements. Each day the results of automatic monitoring by total station and Bassett convergence arrays were down loaded manipulated and back calculated to give structural parameters for the lining. This process was repetitive and laborious and was a clear target for automation.

In the pilot, the data was provided to the MissionOS system and after pre-processing to give diametric movements the results were exported to a simple FE solver to calculate the bending moments and displacements at the joints.

The final display linking daily progress, observed movements, predicted movements and derived structural parameters was set up within the MissionOS canvas screens.



Above: Liantang/ Hueng Yuen Wai boundary crossing project. Relative distance vs date in MissionOS

CONCLUSIONS

The work on these projects demonstrated how effective systems targeted at site management processes can lead to significant efficiencies and improvement in response time, transparency and control giving a reduction in project risk. Management of data within web based structured data repositories means that data is always available for use and presentation reports can be produced and formatted as required

Questions from the floor

Roger Bridge (then BTS Chair): How do you find using the cloud system via the internet with regards to various speeds across the world?
Answer: I gave a talk at the ICE about a year ago – where I did a live demonstration at lunchtime where the bandwidth dived appreciatively – so it is a challenge. We always make sure the data is pre-processed which can be accessed via a normal 3G wireless system.

Peter Wright (CH2M): In your work at Singapore, Hong Kong and around the world did you find that different contractors had different data management systems – and how does it all work together with various clients and contractors to get a sensible understanding?
Answer: In Hong Kong we performed the role as an Independent Monitoring Consultant (IMC) where we monitored for all contractors and clients and had an interface role and where we provided a layer on top to combine all the information for use by the client. We always have a conversation with the suppliers asking how we get the information in so that it can be displayed. The contractors can carry on doing their monitoring on their own and we manage the information and only pass on the relevant information to the client. We provide an over-arching system to give the client what it requires.

Mike McConnell (Balfour Beatty, retired): The future potential is interesting particularly regarding SCL. Is there any logical reason why the concept of actually imbedding something as small as an IPhone into the SCL couldn't be used in the same way?

Answer: Definitely possible, there are devices out there now which are very small and can be embedded but they do need to be protected a bit more to get into the linings.

Frank Mimnagh (London Underground): I am interested about the instrumentation put into tunnel segments. Can you elaborate on what came out?
Answer: They are on site about to be installed.

Frank Mimnagh (London Underground): Regarding battery life – how long do they last?
Answer: We are reading at 5 second intervals and the battery life is 3 months but that is just for recording. Batteries drain more when communicating so downloading is done by someone actually going on site and downloading to their mobile phone about once per day.

David Hindle (OTB, retired): This was a very important presentation for the whole industry. It shows improvements in instrumentation and real time monitoring and is dragging SCL technology back to being an observational method and trust it will bring improved sanity and confidence in design.
Answer: I agree and would add that the data needs to be kept alive and made available to people so that they can use it to learn and develop empirical relationships. Information tends to get lost and one of the advantages of keeping information on a cloud system is that it can be used for many years and downloaded at any time.

Rapporteur: Nick Tucker, Mott MacDonald

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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

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

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

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

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

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

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

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

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

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

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

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

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/

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

World Tunnel Congress
20-26 April 2018
Dubai, UAE
The World Tunnel Congress heads to the United Arab Emirastes in 2018, and demonstrates the rise of the Middle East to the centre stage of the global tunnelling market.
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:

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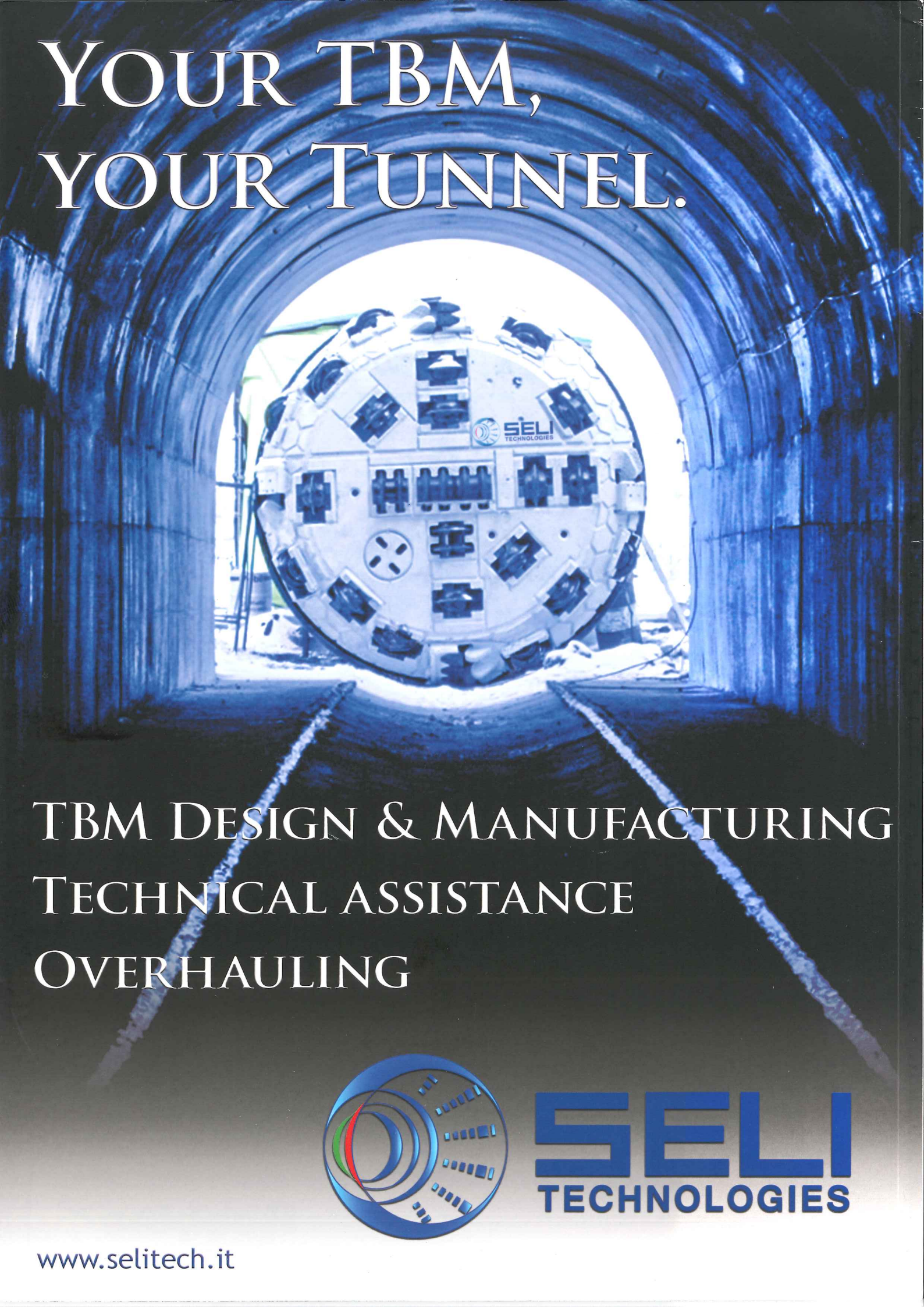

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