

INTERNATIONAL EDITION

April 2014

Tunnels

AND TUNNELLING

*World's first
variable density
slurry machine
reaches daylight
in the Klang Valley*

South East Asia

BIM

Waterproofing

**BREAK
THROUGH**



rapid

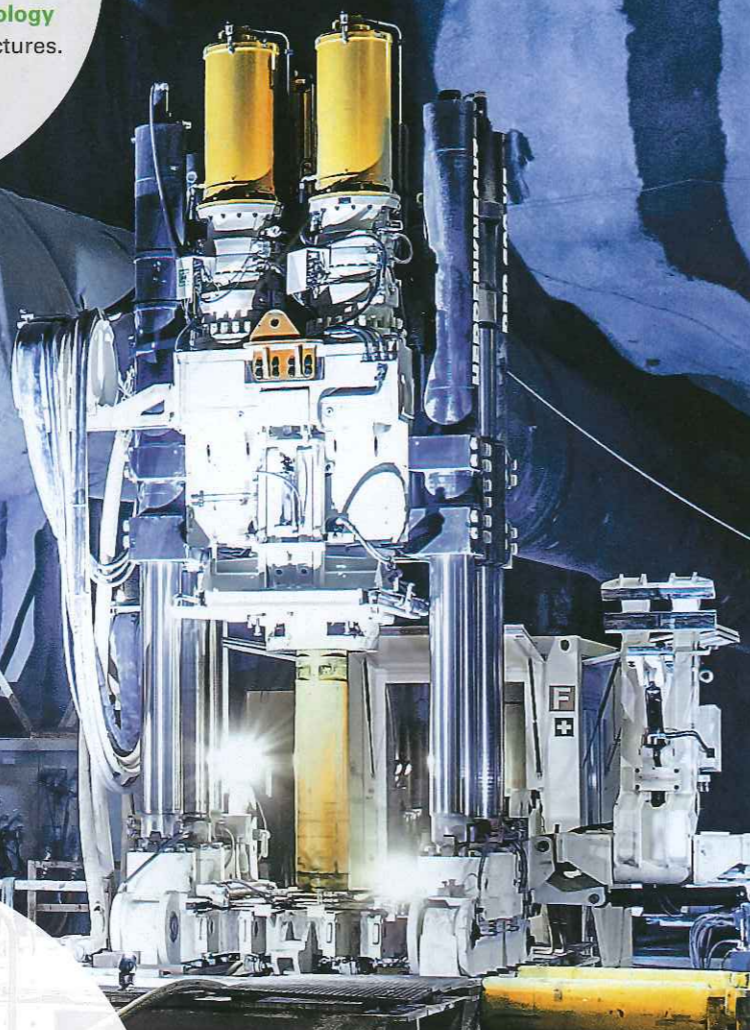
High-speed through stable rock: **Herrenknecht Mining Technology** for efficient mining infrastructures.

robust

Powerful **Herrenknecht Raise Boring Rigs** drive deep, wide and fast. The proven rigs with **high torque and thrust forces** are unique in the mining market.

results

High efficient variable frequency drive: The RBR shows its strong design and flexibility at the construction of two shafts for the **Nant de Drance hydropower plant** – and in other projects around the world.



Pioneering Underground Technologies



GET MINTED

SINCE ECONOMIST Jim O'Neill coined the MINT countries (Mexico, Indonesia, Nigeria and Turkey) there has been a lot of hubbub and guessing games from analysts and investors keen to make a quick buck. The BRIC countries identified by O'Neill in 2001 (Brazil, Russia, India and China) went on to be economic powerhouses and massively fruitful for the tunnelling industry. Mexico is already a hot bed of tunnelling activity, especially in the city. Indonesia has been making noise about many large tunnelling project. Turkey has undertaken some very impressive builds, including the Marmaray tunnel crossing the Bosphorus. But the country holding the most intrigue is Nigeria.

The country's wealth is founded on its natural resource, primarily oil and gas resources, and is strengthened by its rapidly growing population (now over 160M). This month Nigeria is expected to surpass South Africa as the largest economy in Africa by GDP as it rebases it's reporting.

Rebasing, in brief, is changing the base year for measuring a country's GDP. A GDP is calculated against the base year and various assumptions made. If the base year is not a fair representative of the make up of a country's economy then it will not give an accurate view.

The impact of the rebasing is a leap of confidence of investors and further impetus to the economy.

Nigeria is not a big tunnelling country. The major infrastructure developments are largely associated with the oil and gas works in places such as Bonny Island. However, without a pressure to bury the utilities or natural obstacles to overcome, these developments have not led to great tunnel projects.

However, tunnel developments are already being

Jon Young
Editor




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



mooted. The Economic Community of West African states has a 1,200km rail line planned from Nigeria to the Ivory Coast. The line will follow the coast through Benin, Togo and Ghana. It will cost an estimated USD 59bn and will involve tunnelling yet to be identified.

However the real activity will come in closing the infrastructure gap and accommodating for urbanisation. Lesson here can be learned from the experiences of India and China and it is vital ambassadors for the tunnelling industry are in Nigeria to aid in planning.

Chief amongst our activities should be input into the National Integrated Infrastructure Masterplan. This 30 year, USD 2.9tn plan to bring a basic level of road, rail, water and sanitation infrastructure to the country, will set the blueprint for the country's development and tunnelling activities. Buried infrastructure should be at the heart of this plan 

This month...

10 YEARS AGO

After 18 months of tunnelling beneath the UK's capital, all six of the London tunnels have been completed on Section Two of the Channel Tunnel Rail Link (CTRL). The 8.15m concrete-lined tunnels run an impressive 35km. A total of six TBMs were used to excavate ground conditions that varied from London Clay to Thanet Sands and chalks. Overall, expected advance was predicted at 75m per week, but actual progress across all six drives was 100m per week, with a best seven-day performance of 282m.

Tunnels and Tunnelling, April 2004, p.16

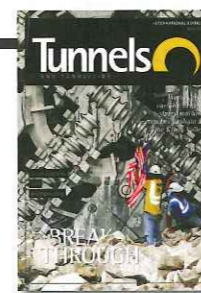
20 YEARS AGO

Tunnelling has been proposed for a Vancouver crossing dilemma. The city's Lions Gate Bridge is to be either replaced or upgraded. Four tunnel proposals, including a novel proposal for directional drilling, are being considered. This interesting concept is unproven for the tunnel sizes being considered. It is understood the contractor would drive a shallow tunnel on a vertical 25,000ft radius curve through bedrock, lay rails and then feed concrete tube segments on to the rails. Segments would move under their own weight and emerge at the far portal. Although successfully used by Greater Vancouver Water district to install 2m diameter water mains, the technical panel notes that the grade of the approaches as determined would be too steep.

Tunnels and Tunnelling, April 1994, p.11

Cover

The world's first variable density TBM reaches daylight in Klang Valley, as Malaysia tackles difficult ground



Next issue

In the next issue, *Tunnels* heads to Brazil for WTC 2014. A special focus is on the new refuge chamber guidelines published by Donald Lamont on behalf of the ITA this year, as well as a look at TBM data analysis, and failure mechanisms incorporated into GBRs



KVMRT PROJECT

Sungai Buloh to Kajang Line
Kuala Lumpur, Malaysia

Successful breakthrough of both CREG EPB machines on the first MRT line

CR50 completed first drive on 24 December 2013 – rates up to 345 m/month

CR51 completed first drive on 16 January 2014 – rates up to 330 m/month

CTE Ltd congratulates Main Contractor MMC Gamuda
and subcontractor Nanyang on a job well done
and looks forward to the second drive for both machines later this year

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The latest project updates, milestones, corporate changes, announcements, and tunnelling advances from jobsites, factories, and design offices all around the world
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Dense urban tunnelling makes for a tight squeeze in Singapore, TBM manufacturer Robbins provides this view of some of the requirements, challenges, and progress made while tunnelling under the island city
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Bhavani Krishna Iyer, MMC-Gamuda
The Klang Valley MRT project recently saw the breakthrough of the world's first variable density slurry TBM. MMC-Gamuda JV delves into the need for the system, geology, and experiences on the SMART project that called for a new type of TBM to avoid some of the earlier project's challenging ground conditions

Waterproofing

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Mike Harper, Stirling Lloyd
The growing popularity of sprayed waterproofing membranes for use in NATM/SEM/SCL tunnels has been highlighted on the Buenos Aires Metro, the mass transit system that serves the Argentinean capital. One supplier, Stirling Lloyd gives this case study from the South American project

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Patrick Reynolds, technical journalist
As building information modelling begins to play a bigger role in tunnelling projects, engineering nous is still king according to clients. *Tunnels* also takes a look at the lesser-known TIM offering of UK-based London Bridge Associates
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Samoter is the main Italian event dedicated to earth moving, site and construction machinery and is a leading reference show in Europe. This year's event in Verona, Italy hopes to build on the 2011 attendance of around 1,000 delegates from the earth moving and machinery sector



Contributors

Desiree Willis

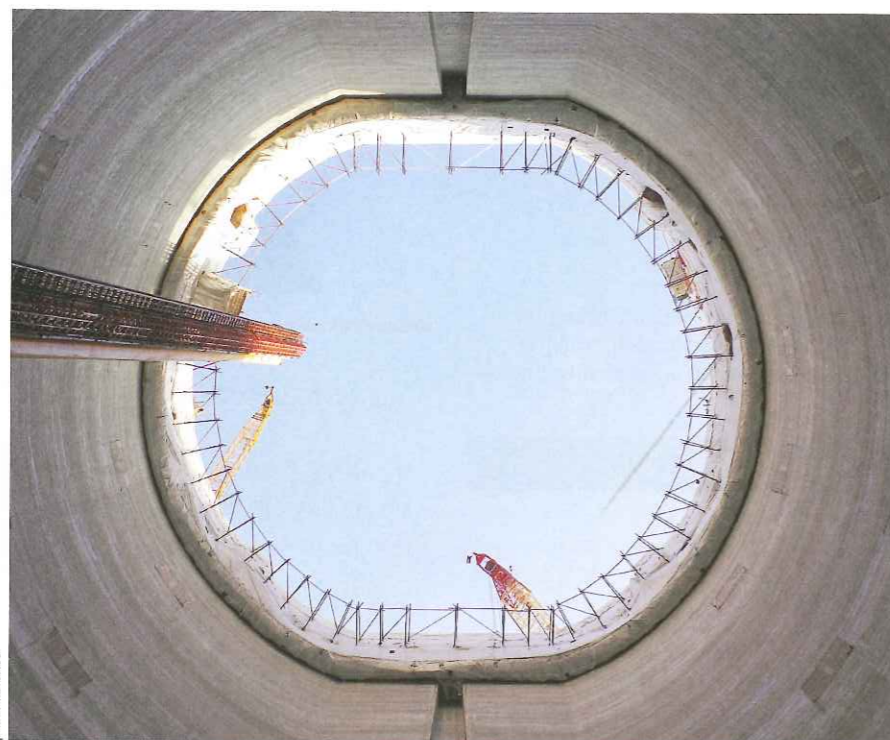
Desiree Willis has worked for The Robbins Company for the past eight years as a technical writer. Documenting tunnelling projects for rail, water, sewer, road and other types of civil infrastructure. She has explored a wide variety of editorial topics in the tunneling industry for *Tunnels*, from projects under high cover to soft ground TBM design. In this issue she covers some of the demands facing tunnelling in the dense urban environment of Singapore. Read her on p.17

Gusztav Klados

Gus is a leading Hungarian tunnel engineer currently working for MMC-Gamuda, having worked around the world on several projects. Klados worked as Lead Engineer or Project Supervisor on several big projects including the SMART Tunnel in Malaysia, the Channel Tunnel, the Metro Systems in Delhi, Athens, Calcutta and Budapest. Klados also worked as a Building Manager in Lesotho, South Africa, where he was building a section of the Northern Water Transport tunnel, later he acted as the Chief Building Manager for the Metro Lines 2 & 3 of Athens. From 2002-2007 Klados was the Senior Project Manager on SMART

Satpal S Bhogal

Satpal Bhogal is a British national with forty three years of experience in the design and management of civil and structural engineering projects in the field of transportation and industrial and commercial buildings. Of this, 27 years spent working in the Asia Pacific region on major transportation projects. Some of the projects Bhogal worked for are Singapore MRT, Taiwan High Speed Rail, Kaohsiung MRT and Mumbai Monorail.



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Discover more...



GRANDS PROJETS

Strict rules for prequalification on Omani rail project

Omani Strict prequalification criteria prescribed by Oman Rail mean that only international contractors with proven and solid experience in the design and construction of railway infrastructure can bid for the key design and build (D&B) package of the national railway project.

Omani contractors are expected to form joint venture partnerships or forge alliances with the prequalified bidders when tendering for the main D&B package, covering Segment 1 of the network, opens in the third quarter of this year.

Prequalification documents were floated recently for the Civil Infrastructure and Railway Track D&B Contracting Services Package (main contractor). Similar documents were also issued for the prequalification of contractors for Railway Technology Systems.

Interest in either package is understood to be strong with scores of international, and local companies as well, collecting documents since the prequalification process opened on 17 February, officials say.

But in a clear demonstration of its intent to develop high-quality and robust rail infrastructure, Oman Rail has set stringent minimum qualification criteria that seek to attract only the world's finest rail contractors to participate in the bidding process.

Contractors seeking to prequalify for the D&B package must have experience in the final design and construction of a single railway infrastructure project in the last five years with a total project construction value of more than USD 1bn. Also, they should have undertaken the detailed design and construction of at least one railway tunnel or

FCC CONSORTIUM GETS DOHA METRO RED LINE CONTRACT

Qatar A consortium led by Spain's FCC, has won a EUR 506M (USD 702M) contract to build a section of the Doha Metro red line, according to Qatar Railways, which is responsible for the construction of Doha's 354km, four-line metro.

The winning consortium also comprises Archirodon (Greece), Yüksel (Turkey) and Petroserv Ltd. (Qatar). The execution period is 31 months and the project will create more than 1,000 jobs.

In the bidding process, the FCC-led consortium competed with groups from

Germany, Italy and South Korea, among others.

The contract includes building three elevated stations (Barwa Village, Al Wakrah and Qatar Economic Zone) at the southern end of the line and a 6.97km elevated section, plus putting the road through tunnel at the entrance to Al Wakrah.

The total budget for the Doha Metro project exceeds EUR 20bn (USD 28bn).

A group led by Impregilo, Italy, won a contract last year to construct a 13km underground section of the Red Line.

road tunnel of at least 500m in the last five years.

Crucially, prospective bidders should also have experience in the final detailed design of railway civil infrastructure for at least one major railway project in the last five years covering at least 200km of double track (with design speed of at least 160kph). These minimum qualification criteria underscore efforts by Oman Rail to procure a high-standard network that is durable and performs well over the long-term.

They also take into account local weather conditions and the desert environment, as well as the need to ensure the timely completion of the line, while also achieving the highest possible In-Country Value.

Targeted for initial implementation is a 171km segment from Sohar City to Al Buraimi on Oman's border with the United Arab Emirates. As part of its scope, the selected contractor will undertake a detailed design based on the preliminary design submitted by Italferr, the Italian rail consultancy appointed as the preliminary design consultant for the national railway project.

The final detailed design will cover the alignment and earthworks, railway track, tunnels, bridges and other structures, operations &

maintenance centre, ancillary facilities, railway stations and utilities. Civil works constitute a key component of the D&B package. It covers all the required earthworks, track work, switches and crossings, construction of railway depots, freight and operational facilities, railway maintenance compounds, highways and access roads, drainage channels, railway embankments and sand mitigation zones.

Also as part of its remit, the D&B contractor will build all structures, including railway tunnels, under-bridges and over-bridges, camel bridges, culverts and crossings for pipelines and utilities. Facilities for freight, loading and unloading, operations and maintenance buildings, are also included.

Work at tunnel site begins 24 hours after Selangor water deal

Malaysia Work on the Pahang-Selangor interstate raw water transfer tunnel project has resumed a mere 24 hours after signing the memorandum of understanding (MoU).

The agreement gave the federal government the green light to proceed with the project that had been put on hold for the past five years.

The government claims the tunnel will meet the

water needs of Selangor, Kuala Lumpur and Putrajaya until 2025.

It will channel raw water, up to 1.8bn litres per day, from Sungai Semantan, Pahang, to a plant in Sungai Langat, which has the capacity to treat 1.1bn litres per day.

Energy, Green Technology and Water Minister Datuk Seri Dr Maximus Ongkili, who officiated the groundbreaking ceremony at the tunnel site in Hulu Langat on 27 February said the 44.6km tunnel stretch was expected to see its first drop of treated water by September. However, he confirmed it would only become operational once the treatment plant is completed, in the next 39 months.

"The tunnel is already 95 per cent complete. It is only the entry from the Pahang side and the two intakes," he said. "One is the damp and the actual intake station which will complete in July."

Ongkili said he had faith in the Selangor government's leadership and predicted that the state would take over the four water concessionaires within the next three months.

The tunnel is being built with a soft loan of MYR 2bn (USD 0.6bn) from the Japanese International Cooperation Agency (JICA). There is a 40-year repayment period for the tunnel through the Titiwangsa mountains.

Xinjiang's longest rail tunnel completed

China The longest railway tunnel in northwest China's Xinjiang Uygur Autonomous Region was completed on 28 February, Xinhua News Agency reported.

Spanning 22.5km, the left part of the Zhongtianshan Tunnel was finished, making the tunnel the longest of its kind in Xinjiang and the third-longest in China, according to the Urumqi Railway Bureau (URB).

Undertaken by the URB and the China Railway 18 Bureau Group Co., the tunnel took about seven years to build. Its right section was finished in September 2013.

The tunnel is part of Nanjiang Railway's second trunk that links Turpan with Korla in southern Xinjiang. The 333.9km-long line, expected to begin operation at the end of 2014, will slash train journeys by 122km.

Crossrail's eighth TBM launches

Great Britain TBM Ellie has

begun her journey from Pudding Mill Lane to Stepney Green in London's East End, Crossrail announced late last month. Ellie is the eighth Crossrail tunnelling machine to be launched and the last to be inaugurated.

Ellie broke ground near Queen Elizabeth Olympic Park and will go 30m below ground on her 2.7km journey to Stepney Green, before breaking into one of Europe's largest mined caverns later this year. The tunnel will form part of Crossrail's north east spur from Whitechapel to Shenfield in Essex.

Ellie is staffed by 20 people, weighs 1,000t, is 150m long and 7.1m in diameter. Her sister machine, Jessica, completed the journey from Pudding Mill Lane to Stepney Green on 3 February and in the coming weeks will be taken to Limmo Peninsula near Canning Town in east London, where she will begin Crossrail's last tunnel drive towards Victoria Dock Portal.

"Crossrail's continuing progress is evidence of Britain's ability to deliver

large scale infrastructure projects on time and within budget," said Andrew Wolstenholme, Crossrail chief executive.

TBM completes Mumbai water tunnel bore

India A Robbins Main Beam TBM completed its drive on the Mumbai Water Tunnel earlier this year.

Robbins provided both the 6.25m diameter TBM and conveyor system for the project, a water supply tunnel.

Joint venture contractor Unity-IVRCL (UIJV) was pleased with the hard rock machine and the support provided by Robbins during the project, Robbins stated.

"The TBM was good in hard rock, and we reached high rates of 870m per month and 58m per day, both records for TBM tunnelling in India," said Pravin Titare of Unity.

"We were able to achieve this due to the good performance of the machine and a conveyor system for muck haulage in place of conventional methods."

Now completed, the water transfer tunnel will provide Mumbai's approximately 20.5 million residents with a consistent flow of clean drinking water, even during the seasonal monsoons that formerly contaminated the city's water resources.

Crossrail moves to employ more women

Great Britain Crossrail has revealed that almost 30 per cent of people building Europe's largest infrastructure project are women. This is compared to 20 per cent of job roles across the UK construction industry. Crossrail stated is seeking to boost the representation of women working in construction, particularly in engineering roles where the UK has the lowest representation of women of any European country, with

just 8.5 per cent of engineers women.

Ailie MacAdam, central section delivery director, in charge of delivering the new tunnels and stations in central London and Docklands, said: "Crossrail is being built by some of the UK's best construction and tunnelling engineers. Over the next 10 years, as an industry, we need to double the number of people with engineering qualifications to meet the demand for skills. To achieve that, more must be done to attract and retain young women to what is a fabulous and rewarding career. Crossrail and its contractors regularly visit London schools to run engineering workshops and to inspire the next generation of construction workers and engineers. But a joint effort is needed between schools, parents, government and industry to encourage more young people, including women to pursue a construction career."

Work starts on Beijing Shenyang high-speed railway

China Construction has begun on a high-speed railway linking the Chinese capital of Beijing and Shenyang, capital of northeast China's Liaoning Province, Xinhua News Agency reported on 3 March, quoting local authorities.

Work on the 8.8km Sanleng Mount Tunnel started on 28 February to spearhead the Beijing-Shenyang railway project, according to a statement from the provincial transportation department.

The tunnel will stretch from the city of Beipiao to Fuxin Mongolia Autonomous County. It will be completed within 33 months, the statement said. The 709km Beijing-Shenyang railway project is expected to be finished within five years, after a total investment of CNY 124.5bn (USD 20.3bn).

New underground car park opens in Dubai

UAE A new underground parking lot in Jumeirah Beach Residence (JBR), in Dubai, has opened, adding a much-needed 1,200 parking spaces in the community.

Located directly on the beach front and bordered by the popular boulevard, The Walk, JBR is a much-preferred destination for tourists and local visitors alike. As a result, a continuous flow of traffic runs through the narrow streets every day, and until now parking space was a scarce entity.

Located in the middle of the promenade, it is largest car park area for visitors in JBR, and the most accessible as it is a straight drive-through from Al Gharbi Street, which crosses Dubai Marina waters to Sheikh Zayed Road.

To improve parking facilities for visitors, the additional car parks were built. With the development of the underground car park, there will be far greater availability of parking, Dubai Properties Group (DPG) said in a statement issued on 5 March. "JBR has been designed with adequate parking space for all residents, in accordance with Dubai's standard planning regulations."

Responding to queries about the future plans of DPG for the community, the developer said: "A number of DPG and RTA (Road and Transport Authority) initiatives are being implemented to address both visitor and resident parking and traffic issues. The Pay Parking system is a great example of one of the measures taken to improve parking for visitors to The Walk at JBR and the application of this nominal fee has resulted in greater availability of parking for visitors.

"In addition, we are creating connectivity points

with future tram stops to address concerns regarding traffic and pedestrian flows."

However, DPG encouraged the use of public transportation, as the Walk is a very popular destination, particularly on weekends.

"Dubai Metro has two stations within close proximity of The Walk (Dubai Marina and Jumeirah Lake Towers)," it said. "We work very closely with government authorities to regulate the flow of traffic to The Walk, especially at peak times."

Korean firm bids lowest for railway contract

Oman Three international engineering and consulting companies submitted their financial offers for the project management consultancy (PMC) contract of Oman's national railway project.

The three international engineering companies who submitted their financial offers are Spanish international general contractor Tecnicas Reunidas; Dohwa Engineering Co, a South Korea-based multi-disciplinary engineering consulting firm; and Parsons International & Co., an engineering, construction and technical and management services firm.

The lowest offer was made by Dohwa Engineering Co at OMR 106.8M (USD 277.4M), while the second lowest bid was quoted by Tecnicas Reunidas at OMR 165.08M (USD 428.77M). The highest price was quoted by Parsons International & Co. at OMR 185.97M (USD 483.03).

In August last year, five short-listed international companies submitted their technical offers for the PMC contract. Around 29 companies had evinced interest when the Ministry of Transport and Communication (MoTC) floated the international tender in June 2013.

The MoTC recently appointed Italferr, the Italian State Railways Group's

TUNNEL UNDER KARNAPHULI TO BEGIN IN YEAR

Nepal Construction work on Bangladesh's first-ever tunnel under the Karnaphuli River in the country's southeast will begin in the next fiscal year, communications minister Obaidul Quader said on 9 March.

The construction cost of the tunnel will be BDT 65-70bn (USD 0.8-0.9bn), Obaidul said, adding that China Communication and Construction Company will invest in the project.

"They have given an offer in this regard," Quader said. "A delegation of the Chinese company will visit the country within a few days."

The feasibility study of the tunnel has already been completed. After construction of the tunnel, a new city will be built on the other side of the Karnaphuli river, he said.

Results of the study have found a 3.4km passageway to be feasible for the tunnel at the estuary of the Karnaphuli river as it ensures connectivity of the nearby city Chittagong with the proposed deep-sea port and Cox's Bazar, a seaside town.

engineering firm, to provide consultancy services for preliminary design of the railway project.

Speaking to reporters, Ahmed bin Mohammed bin Salim al Futaisi, Minister of Transport and Communications, recently said that the tender is with the Tender Board for evaluation and is expected to be awarded shortly.

"The PMC is much required now as its role will be to review the preliminary design," he said. "It is clear that the preliminary design consultant is moving fast and has started submitting the drawings for the first segment. We need PMC to review and approve the designs and hope it will be appointed very soon."

Upon appointment, the PMC will provide overall project management consultancy services, including reviewing the design of the railway network and the contract process.

CBE Moulds for Anacostia and Rennes

France CBE Group will provide the supply of

segment moulds for the lining of the Anacostia River Tunnel project in Washington, D.C., and the new part of the subway in Rennes, France, the company announced in early March.

Six sets of moulds will be delivered to Bay State Precast LLC for the 3.84km long Anacostia River Tunnel project in Washington, D.C.

Five sets of moulds will be supplied to the Rennes Line B project for use on a 7.5km long tunnel section.

Each ring is composed of five standard and two key segments with an exterior diameter of 7,620mm a thickness of 305mm and a width of 1,829mm.

For D.C.'s Anacostia tunnel, the segments will be manufactured in the Bay State Precast LLC factory located in Brandywine, Maryland.

The CBE carousel which will accommodate these new moulds, had already been used successfully for the production of the Blue Plains tunnel segments, including the anchored gasket technology. The Blue Plains tunnel is also being constructed for DC Water.

SINKHOLE CAUSE IDENTIFIED IN OTTAWA

Canada Tunneling stopped at the East Portal on the Confederation Line's tunnel in Ottawa due to a roadway collapse on February 20.

Mining crews from Rideau Transit Group (RTG) noticed excessive loose and wet material start to fall, between the tunnel support pipes, from the left side area of the tunnel crown onto the tunnel floor. This material continue to ingress and, despite efforts to stabilize it from below, only stabilized after a sinkhole, roughly 8m in diameter developed.

Damage from the sinkhole was limited to city utilities that crossed its path. Extensive monitoring points in the area have confirmed that no building settlement of concern occurred, and no workers or other persons were injured as a result of this event.

A report released on March 21 by the city of Ottawa, identifies that the tunnel crossed beneath a previously excavated construction pit that was deeper than the known utilities and likely extended from bedrock to the surface.

"The shape of the old pit closely matched the shape of the sinkhole that opened up; also the pit edges display features of the previous sheet piled support."

TURKEY'S BIGGEST WATER TUNNEL COMPLETED

Turkey's Turkey's largest, and the world's fifth largest water distribution tunnel has been inaugurated by the Turkish Prime Minister Recep Tayyip Erdogan in the southeastern city of Sanliurfa in the Suruc district, Anadolu Agency reported on 9 March.

The 17km Suruc water tunnel has been under construction for the last three years or so as part of the Southeastern Anatolia Project, which aims to boost the economy and agriculture in an impoverished part of Turkey.

The tunnel will carry 90cu.m of water per second from Atatürk Dam, Turkey's biggest, into the Suruç Valley in Southeast Anatolia to irrigate

almost a million hectares of farmland.

The planning of the tunnel, which forms the most important stage of the Suruç Valley Pumped Irrigation Project, was started in 1990 but could not be completed for years.

Erdogan said that with the new developments almost 200,000 people would be employed in the region and it would contribute an estimated amount of more than USD 140M to the regional economy per year.

Erdogan added that once the water pump stations for the tunnel are completed at the end of this year, the total cost of the project would exceed USD 900M.

Attention shifts to proposed undersea tunnel

Malaysia Now that the second bridge linking Penang island to the mainland has been opened, focus is shifting back to the controversial proposed undersea tunnel.

With the feasibility study on the tunnel due as *Tunnels* went to press, a lawmaker from the nation's Democratic Action Party said Penang needs pedestrian-friendly towns and an efficient public transport system before building the tunnel.

A government spokesman said if the state can get the tunnel project going without needing federal funds, it should try the same approach to implement an efficient public transport.

"Considering the critical need to prevent the island from slowing down into a traffic gridlock, it seems wise to use land swaps to fund pedestrian-friendly infrastructure and provide capital investment for trams first before funding an undersea tunnel."

The spokesman said in the Penang Transport Masterplan, the tunnel was ranked 'low priority' compared to improving roads for pedestrian safety and having a good public transport

system. The spokesman added the masterplan recommended trams between George Town and the airport in Bayan Lepas, and an improved bus system. A tunnel will only be needed around 2030, she said, although acknowledging that the state also cannot wait until then to start planning a project that will take many years to complete.

The spokesman also referred to Chief Minister Lim Guan Eng's comment on 2 March that the tunnel will serve as an economic catalyst for northern Seberang Prai and reduce traffic congestion on the island.

It had been reported that the feasibility study on the proposed 6.5km tunnel by Consortium Zenith BUCG Sdn Bhd is being paid for with a land swap deal between the company and the region.

Consortium Zenith has been granted a 3.64ha. plot of land on Seri Tanjung Pinang 1 (STP1), worth MYR 305M (USD 93M) by the state government to finance the cost of the initial feasibility studies and detailed design works on the MYR 6.3bn (USD 1.9bn) Penang undersea tunnel project, which also include a 4.2km bypass road linking the Tun Dr Lim Chong Eu Expressway and Persiaran Gurney, a 4.6km bypass road linking the

expressway and Air Itam, and a 12km highway.

Consortium Zenith inked a contract with the state to build the four projects in October last year. The deal is for the company to fund and build the four projects in exchange for 44.5ha of land in Seri Tanjung Pinang 2 (STP2) from the state government, and a 30-year toll concession on the tunnel.

STP2 involves the reclamation of 307.5ha in the sea off Tanjung Tokong by developer Eastern & Oriental Bhd (E&O).

The public viewing of the STP2 project exhibition ended on 7 March.

The spokesman said because the tunnel project itself is possible only if the STP2 project takes off, the study of the tunnel must also take into consideration the kind of development STP2 will bring to the area.

"The STP2 man-made island is expected to bring in a 202,500 population, 11,000 to 14,000 additional cars. Other future developments in the Persiaran Gurney area will also bring more people and vehicles," she said.

Plans for first Philippine metro to be presented

Philippines The Department of Transportation and

Communications (DOTC), of Philippines, is set to present the master plan for proposed projects in the airports and railways sector, including the country's first metro in its capital, Manila.

Cosette Canilao, head of the public private partnership (PPP) Center, said in Manila on 18 March that among the projects to be presented is the Mass Transit System Loop, a 12km underground rail that will connect Bonifacio Global City, Makati Central Business District, and the Mall of Asia in Pasay City.

Transportation Secretary Joseph Emilio Abaya earlier said a feasibility study on the subway line would be financed by the Japan International Cooperation Agency (JICA).

The DOTC held a forum on 20 March titled, 'Invest Transpo PH' to target infrastructure and construction companies, airport operators, rail operators, and financing companies. The event, Canilao said, aimed to highlight investment opportunities under the PPP program of the Aquino administration.

"The DOTC will conduct a market sounding for the rest of the airports and some of the rail projects that they are doing right now," she said.

A JICA study showed that at least 200km of railroad and more than 100,000km in road network are needed to address the congested metropolis.

With Metro Manila's rapidly urbanising cities, the DOTC plans to implement the project to improve inter-city linkage by providing a higher capacity public transportation system that would facilitate fast and convenient mobility of goods and services.

Given Metro Manila's current infrastructure, it was also determined that the rail line of approximate length 12km would need to run mostly underground, making this the first metro in the country.

Melamchi Tunnel may be completed by mid-2016 despite teething troubles

Nepal Much to the dismay of the residents of the water scarcity-hit Kathmandu valley, the Nepal government's ambitious yet controversial Melamchi project has hit rough weather yet again, sources in Kathmandu said 9 March 2014.

The Melamchi Drinking Water Project - the future of which appeared bleak after China Railway 15 Bureau Group, a Chinese construction company, unilaterally cancelled a tunnel-construction contract with the government in November 2012 - was revived early this year. After CMC Cooperativa Muratori e Cementisti di Ravenna, a leading construction company of Italy, agreed to complete the diversion tunnel construction work, the government had expressed its commitment to supply water of Melamchi River to the Kathmandu Valley by mid-2016.

The contract involves the construction of the tunnel to divert 170 million litres of water per day from Melamchi to Sundarjal (in Kathmandu), where the water would undergo treatment before going into the bulk distribution system.

"You people (the valley residents) should feel relaxed. You all will get to drink Melamchi River's water by mid-2016," Kishor Thapa, Secretary of the Ministry of Urban Development, reportedly said on 1 January 2014 - just after Italy's CMC company resumed the tunnel construction work. "The Melamchi project will be completed in just 30 months."

However, two months later, the Italian company is yet to start fully-fledged tunnel construction works. According to Krishna Acharya, Executive Director of the project, heavy equipment ordered by the Italian

company is yet to arrive at the project site.

As per the schedule, the company should have started full tunnel construction works two weeks ago. However, due to the delay in transportation, timely completion of the tunnel construction work remains uncertain.

However, Acharya says they are still hopeful that the Italian company will meet the deadline. "The Italian company has assured us that it will meet the deadline by speeding up the work," said Acharya. "So, the initial delay is unlikely to affect the project schedule."

The Melamchi project, which is expected to end the perennial water crisis in the Kathmandu Valley, has faced several ups and downs.

As a result, despite commitments by the government as well as political leaders, its successful completion has always been doubted by the valley residents.

Of late, the Melamchi project had appeared in disarray when China Railway, which was to dig a 26.5km tunnel in four and a half years, dug just 6.5 km of tunnel in more than three years. Later, it returned to China, cancelling the contract from its side, citing its inability to complete the project due to frequent strikes, inflation, problems with payment and lack of support from the government.

Later, on 15 July 2013, the government signed a new contract with the Italian company. The contract with the Italian company will expire in September 2016.

As the Italian company aims to finish the tunnel construction work about six months before the expiry of the contract, the initial delay is unlikely to cause troubles, said Acharya.

The government of Nepal is contributing 20 per cent and the Asian Development Bank (ADB) is providing 80

per cent loan assistance for the tunnel's construction.

...and issues project progress update

Nepal The newly-appointed Italian contractor, CMC Cooperativa Muratori e Cementisti di Ravenna, has constructed 35m of the total 27.5km diversion tunnel of the Melamchi Drinking Water Supply Project in a month, the Melamchi Water Supply Development Board said in a statement issued on 14 March.

As per the earlier decision to provide update on the progress of the tunnel construction activity to general public in the first week of each Nepali month, the board issued the statement saying that the contractor's work is found satisfactory.

According to Ghanasyam Bhattarai, deputy executive director of the project, construction of a waste water treatment plant and social empowerment activities in the affected communities, besides the diversion tunnel, are also being carried out as a part of the project.

The Italian contractor was appointed last year after the government terminated

the contract with the China Railway 15 Bureau Group Corporation and China Machinery Industry Construction Group on 25 September 2012 due to their failure to carry out the work. The Chinese contractors constructed only 6.5km of the tunnel in three years or so.

The work was halted after the government terminated the contract with the Chinese contractors in November 2012.

The board then decided to award the contract to the CMC for NPR 7.72bn (USD 79M). The government has itself allocated some NPR 5.24bn (USD 53.5M) for the project this year.

In another development, police rescued five workers on 14 March who were trapped in Melamchi water project's pipeline tunnel in Sundarjal, a village development committee in Kathmandu District in the Bagmati Zone of central Nepal.

The workers were trapped in the pipeline after all the lights underground went off due to an electrical short circuit.

The trapped workers were rescued nearly one and a half hours later. No casualties were reported.

HIGHEST HIGH-SPEED RAILWAY TUNNEL COMPLETE

China Located in the desolate, snow-topped Qilian Mountains, in northwest China's Qinghai Province, and perched at an average altitude of 3,600m to 4,300m above sea level, the world's highest high-speed railway tunnel is expected to be completed this month, according to an 11 March story by Crienglish.com, the official English-language website of China Radio International.

Constructing the tunnel is one of most difficult parts of the process of developing the line linking Lanzhou, the capital city of the northern Gansu Province, with Urumqi, the capital of northwest China's Xinjiang Uygur Autonomous Region, the report said.

The 1,776km Lanxin railway line runs across the Gansu and Qinghai provinces to Xinjiang, which includes traversing the wind-ravaged Gobi Desert.

Residents demand fair deal from floodwater tunnel project

Indonesia Residents of a neighborhood in Bidaracina, East Jakarta, have expressed strong opposition to a tunnel project that would oust them from their land. The city administration should compensate them with similar houses in other locations, instead of moving them to low-cost apartments, the residents say.

'Community Unit Four' head Galuh Radia, who has lived in the area for more than 30 years, said that on behalf of residents, she had delivered a letter of rejection to Governor Joko Widodo, the House of Representatives and the East Jakarta mayor, against the city administration's plan to relocate more than 300 families to several low-cost apartments in the municipality.

"The reason we reject the plan is not only because of the sketchy information, but also due to the fact that, unlike other neighbourhoods in the district, we have never been hit by floods."

She added that the community had not been informed about the tunnel project and the authorities had not held talks with residents to familiarise them with the project and to discuss fair compensation for the affected land.

British Tunnelling Society responds to Union criticisms

Great Britain In response to the recent attack by UCATT on the construction industry's perceived failure to train apprentices, the BTS gave the following statement.

"In the tunnelling industry in recent years this subject has been discussed repeatedly, those discussions have included industry clients, the government, some of our major contractors and the BTS.

"We have recognised the problem and tried to develop the situation where we have a steady flow of apprentices, technicians and engineers coming into the industry. We have some sympathy with the notion that companies bidding for public work must employ apprentices but as a bald statement that lacks understanding of the tunnelling industry and the larger construction industry. It is unreasonable to ask contractors to employ apprentices without a real expectation for work on which to employ those apprentices. It is also true that in our industry there is not the continuity to justify direct employment and most employers work with sub-contractors or labour suppliers. This generally works well and the sub-contractors/labour suppliers are responsible employers

who provide a great deal of continuity. However in respect of apprentices Tier 1 contractors and their supply chain do have a role and a responsibility in selecting, sponsoring and ensuring employment for apprentices. The problem that then rears its head is a procurement philosophy that puts client and contractor in boxes having formal conversations only. There is fear of conflicts, there is fear of challenges and it seems our procurement experts do not have the determination or expertise to make procurement processes bring value to a project. In particular this means that by the time the contractor is in place it is too late to train apprentices to work.

"Our view is that contractors should be told that if they expect to work on a project they need to join in the recruitment and training effort at an early stage (before they are in contract) to demonstrate their commitment and win points for a later selection process. We should not let this be in the 'too difficult' basket, our young people's lives are being prejudiced. The new is of course not all bad in our tunnelling industry, we have TunnelSkills, an organisation composed of the employers of the industry who work with ConstructionSkills to raise standards in the industry,

developing apprenticeships, NVQs and specialist training courses. In this they are supported by their members, ConstructionSkills and the BTS. The BTS of course focuses more on the technicians and engineers but tries to be very inclusive welcoming all to their meetings and courses. Every year they run a very well attended week-long course, using expert volunteer lecturers from industry on Tunnel Design and Construction, and a similar two day Underground Health and Safety Course. "The MSc in tunnelling course which goes from strength to strength at Warwick University is unique in the level of industry involvement as organised by the BTS and all graduates to date have walked into employment. Nick Raynsford complains of a lack of imagination and we have a measure of agreement with him, but can we imagine what we need to do correct the rut our construction industry has fallen into? Have we the vision to do really do things differently as HS2 as Sir John Armit encourages us to do. If so we must provide more support and incentives to industry (not the training providers) and then challenge industry to take the lead defining how they can make it work. There are great opportunities to rebuild our industry and even export, but it will take industry and government, clients and contractors to be working a great deal closer together and most importantly to take it out of the political arena. So many ideas fail because there appears to be no votes in it. We have concerns that the summit proposed will go for a quick political fix and that is not the answer. Trainers are all too ready to spend taxpayers' money on training.

"This is not a training issue. That misses the point. The issue is far wider and perhaps less politically acceptable."

EVERGREEN LINE IS GO

Canada The start of Evergreen Line tunnel construction and officially naming the TBM for the 2km tunnel under Vancouver, took place in early March, the government of British Columbia announced recently.

The machine has been named 'Alice', after Alice Wilson, a famous Canadian geologist.

"Our Government is pleased to invest in this project that will create jobs and boost the regional economy," said James Moore, minister responsible for British Columbia and member of parliament for Port Moody-Westwood-Port Coquitlam, at the ceremony. "The Evergreen Line

will not only provide Metro Vancouver residents with an expanded, efficient and environmentally sustainable transit system, it will connect communities and improve the quality of life for all residents of the region."

Premier Christy Clark added: "With today's christening we can start to create the longest rapid transit system in Canada. We promised to open the line by summer 2016... and we're delivering."

The Evergreen Line will run east of Barnet Highway in Port Moody to south of Kemsley Avenue in Coquitlam.

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BLACK FOREST FORMWORK

The third 'Formwork Days' conference was hosted last month in the southwestern Baden-Württemberg State of Germany. Focusing on formwork and tunnel lining in general, the two-day event was sponsored by Herrenknecht and a number of partnership companies. Topics covered included tracking of segments in a worksite yard - allowing for a chaotic efficiency of logistics where space is limited, DAUB recommendations for ring design, history of and future developments for segment reinforcement.

A highlight was an introduction to 'Combisegments' by Jörg Riechers, detailing some advantages of the cast-in inliner for corrosive tunnel scenarios (sewer), compared with traditional one-pass embedded thermoplastic linings, which Riechers criticised in terms of casting practicality and permanent corrosion protection. The timesaving from a reduction in welding and fixing was also argued to be significant (more on this topic to follow in a later issue of *Tunnels*)






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Size of a Human red blood cell and the measurement uncertainty of a coordinate when measured with the Laser Tracker used in VMT's industrial measurement system.

10 µm



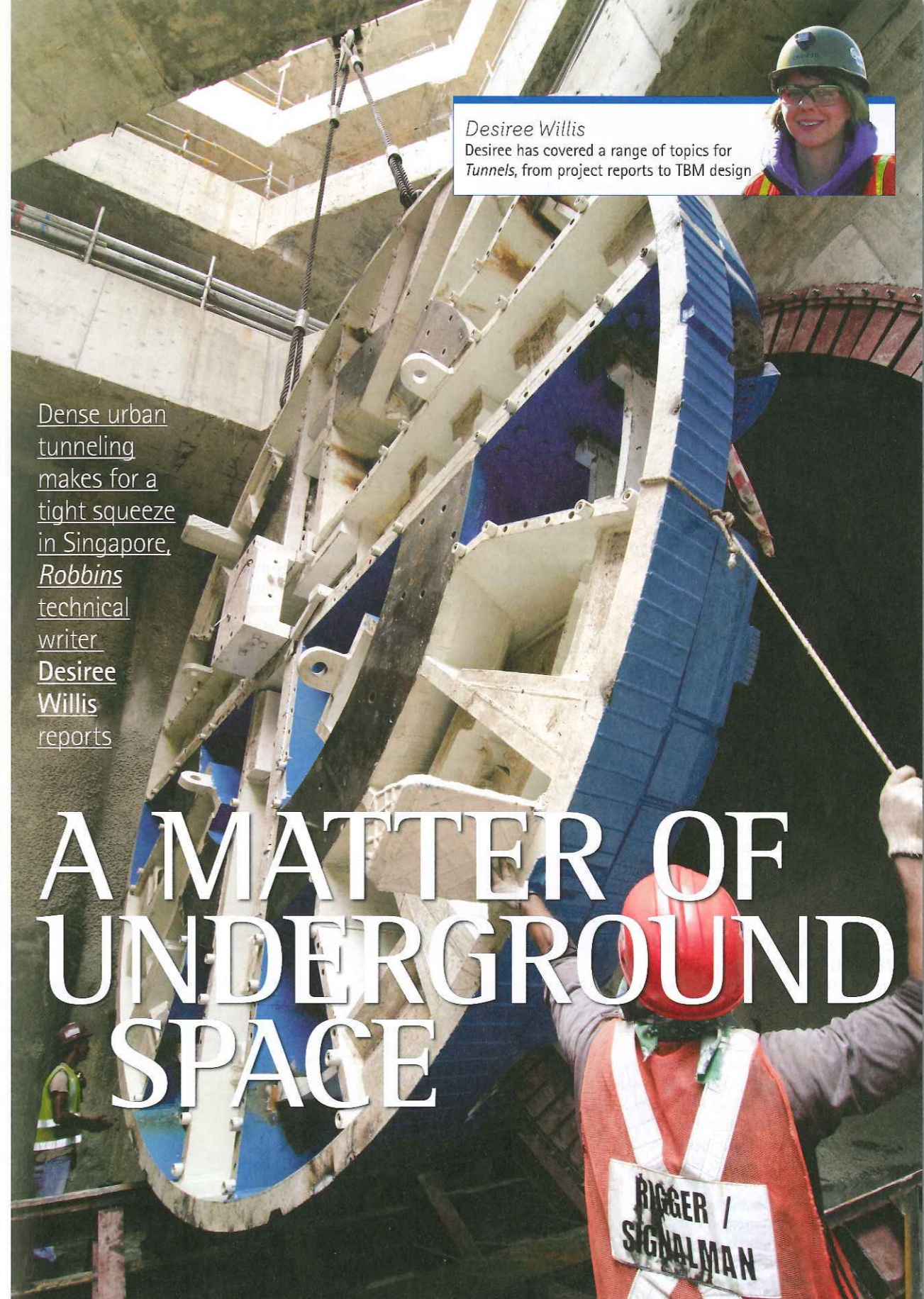
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Desiree Willis
Desiree has covered a range of topics for *Tunnels*, from project reports to TBM design

Dense urban tunneling makes for a tight squeeze in Singapore, *Robbins* technical writer *Desiree Willis* reports

A MATTER OF UNDERGROUND SPACE

BIGGER / SIGNALMAN



"LTA's goal is that Singaporeans are never more than 400m from a station. The multiple contracts at short lengths keep construction times short"

42km of new track with 34 stations. Once complete in 2017, the entire DTL is estimated to serve half a million commuters daily.

It is the goal of the LTA to finish the entire project as soon as possible, including all phases of the Downtown Line. Ultimately, the LTA's goal is that Singaporeans are never more than 400m from a station. The multiple contracts at short tunnel lengths with large amounts of machines are the LTA's bid to keep construction times short.

Plans don't end there: In January 2013, the LTA announced a Downtown Line extension, which will be completed by 2025. Other metro plans in the country include the Thompson Line, which will involve an additional 30km running from North to South, and employ a further 32 TBMs.

COMPLEX LOGISTICS

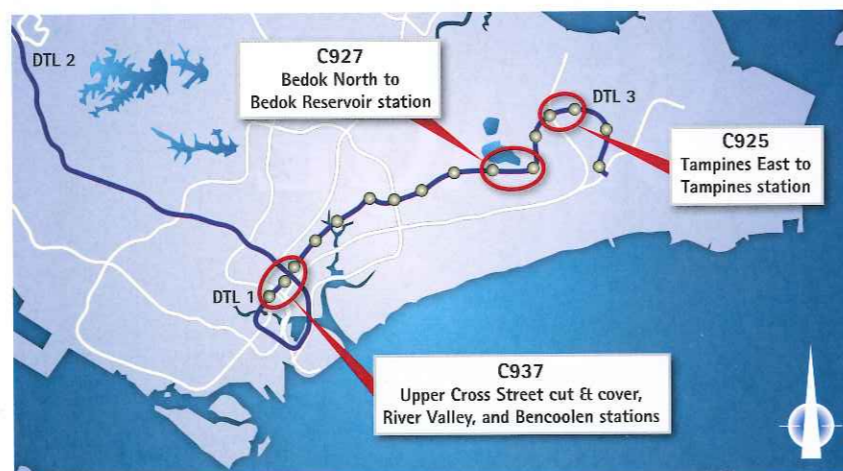
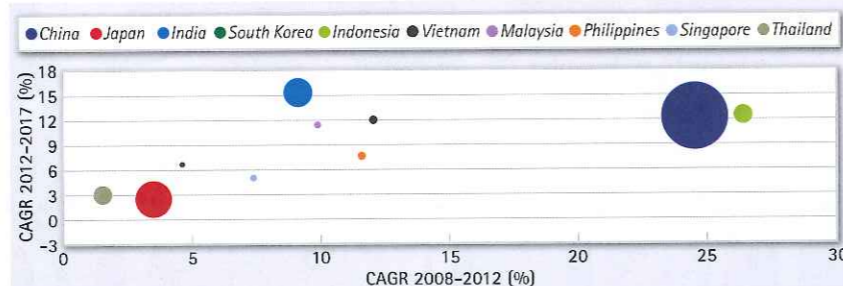
For three of the Downtown Line 3 contracts, C925, C927, and C937, logistics are particularly complex. Each contract includes the construction of shafts, parallel tunnels, and station sites. The geology in Singapore is very complex and can vary radically even along the relatively short contractual tunnel lengths. Multiple core drills were conducted along the alignments, resulting in detailed geotechnical reports.

Contract C925, for 800m long sections of parallel tunnels running between Tampines and Tampines East Station sites, was awarded to Korean contractor GS Engineering & Construction Corporation, who chose to use one TBM to bore the parallel tunnels. The TBM will be dismantled after the first

Above: A Robbins EPB is assembled at shaft bottom on CMC di Ravenna's C927 contract in Singapore

Below, top: Singapore's growth rate in a local context (Timetric data)

Below, bottom: Singapore's Downtown Line 3 is a 21 km long route involving 29 TBMs and 16 new station sites



AT JUST 50m wide and located meters away from condominiums, a school, and busy highways, the C925 jobsite on Singapore's new Downtown Line 3 is a small space to stage a tunneling operation, but it is by no means a unique circumstance in the city-state of 5.3 million people. The jobsites are continuous, stretching for kilometres with multiple machines holing through into neighbouring shafts.

The new construction makes up 21km of tunnel for the Singapore Land Transportation Authority (LTA). The Downtown Line 3 is using 29 TBMs boring between 16 station sites in short bores often less than 1.5km each. By 2017, 39km of new construction will cut commute times in half in one of the world's most densely populated locales.

Lack of space is not the only challenge in Singapore: Ground conditions pose difficulties for both equipment manufacturers and contractors. Geology ranges from clay, mudstone, and sand to complex boulder fields, requiring specialised TBM design and operation.

MASSIVE SCALE OF CONSTRUCTION

Singapore's Downtown Line is one of the most extensive projects in the tunnelling industry today, using more than 50 TBMs in three phases. The machines, all designed for soft and mixed ground conditions, are required to be new and most of them are boring short distances of 1.5km or less, due to contractual stipulations. This unique arrangement has both positive and negative effects on the tunnelling industry. Both phases two and three are under construction, while phase one has been completed.

Singapore's downtown line is the fifth rapid transit route to be built in the country. The entire Downtown Line, including phases 1 and 2, will consist of



drive and transported back through the tunnel to the launch shaft to begin the second drive. Ground conditions based on tests include clays, sand, gravel, and sandstone conglomerate.

C937, consisting of two 780m tunnels driven between River Valley station and Bencoolen stations and two 560m long tunnels between River Valley station and Upper Cross Street, was also awarded to GS Engineering & Construction. For this contract the company chose two EPBs to bore each of the 780m long tunnels and one machine to excavate both parallel 560m tunnels. Sections of the C937 contract make contact with the Fort Canning Boulder Bed, consisting of relatively strong and large rock boulders in a stiff clay matrix. Other ground types include clays, mudstone, siltstone, and sandstone.

Parallel 1.4km lines on the C927 contract running between Bedok Park and Bedok Reservoir Stations were awarded to Italian contractor CMC di Ravenna. The contractor opted for two TBMs for the tunnels, which pass below a canal,

foundations for a pedestrian bridge, and a national park. Based on core samples ground conditions include clays, sand, and sandstone conglomerate.

EPB DESIGN FOR MIXED GROUND

Each of the six 6.6m diameter Robbins TBMs were fitted with mixed ground cutterheads and interchangeable 17-inch disc cutters or tungsten carbide knife bits, depending on the conditions. The opening ratio was custom configured to accommodate varying setups of disc cutters and bits. Wear plate was also added to increase abrasion resistance in rocky conditions. Injection ports in the cutterheads allow for a wide variety of ground conditioning materials to be injected, including foam, polymer, and Bentonite.

As there are strict settlement limits in the Downtown Line contracts, the machines are each using active articulation, which keeps the trust cylinders directly in line with the last segment yet allows the rear and forward shields to move independently of one another in a curve. Equal thrust is reacted on all portions of the erected segment ring, reducing the risk of ring deformation that can lead to settlement. In addition, the machines are utilising two-liquid back-filling. The 'A' liquid, a cementitious grout, is combined with the 'B' liquid accelerant at the nozzle, just before injection into the annulus, allowing the annular space between the ring and tunnel walls to be filled and harden in less than a minute. A notably unique part of each machine's



settlement minimisation program is the ring reformer – a setup used widely on Japanese TBMs but with limited use elsewhere. The device includes two hydraulic jacks that stabilise each Universal concrete, wedge type segment ring during assembly, preventing vertical deformation.

SPACE AT A PREMIUM

The tight urban jobsites in some cases required extraordinary measures—in one case a jobsite on the Downtown Line required moving a section of the Singapore River in stages in order to allow a station site and tunnel to be built directly under it.

Of the jobsites, GS Engineering's C925 site may be one of the smallest: "It's very close to condominiums. We are limited to filling the mucking box during days, and we have noise barriers up. There are noise meters on tops of the condos, and our ambient noise readings are only allowed to average 65 dB, which is a little bit more than ambient noise," said Andy Birch, Robbins Field Service site manager.

The site is additionally near a main road and a school, and though the narrow jobsite is quite long, about 1.5km, there is very little area for storage. A station box directly abuts the back of the C925 tunnel with STEC machines operating at that site, making space a premium.

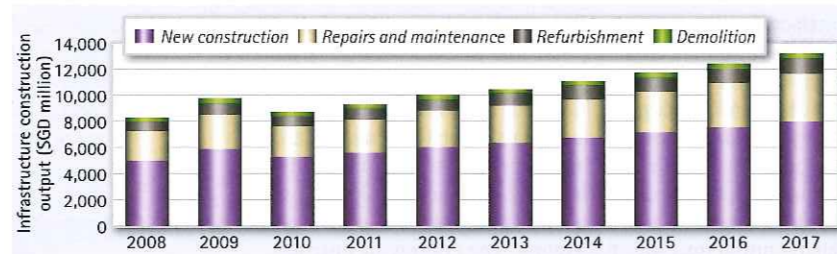
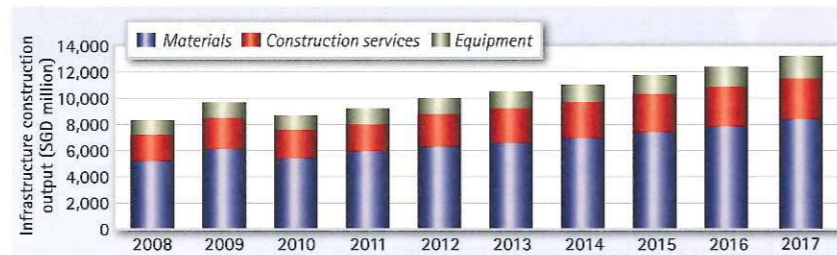
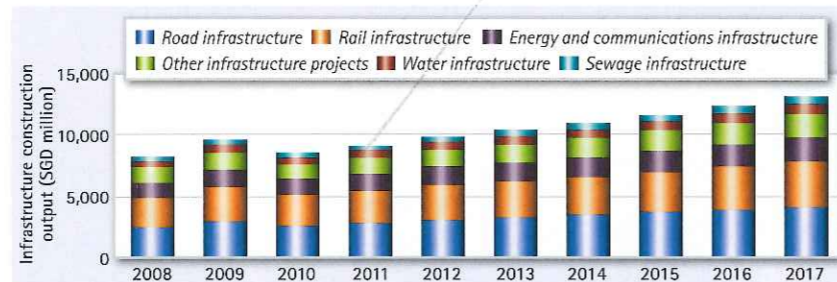
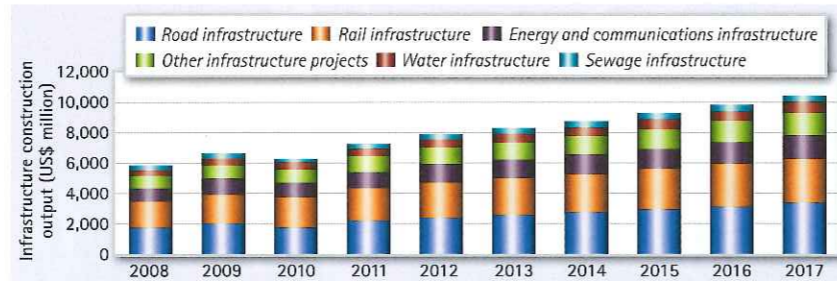
Assembly of the Robbins machine at the jobsite was additionally a challenge: "We had to place cranes on the surface and do load calculations to get the machine down into the shaft for assembly.

"We had to build the TBM on an access between two tunnels, then push it over on jacks to get it into the right alignment for launch," said Birch.

CMC di Ravenna's C927 jobsite using two EPBs was similarly cramped. "We have a small shaft available for the two TBMs, 20 x 20 m.

Both machines bored in the same direction, for twin drives, and passed under foundations for an overhead pedestrian bridge. These tunnels are predominantly under a national park (Bedok Park), and also go under a large 9.5m wide canal that is 3.5m deep for about 400 m of the tunnel," said Chris Knight-Hassell, Project Manager for CMC.

At all of the sites very little muck can be stored on location due to lack of space; instead it is immediately loaded into trucks. The material is designated for landfill to build up the shoreline of Singapore.



Above: Singapore infrastructure construction market factors analysed and projected forward (Timetric data)

C925 Site: Fast Advance with Specialised Muck Removal

At C925, the machine was launched from the small shaft site in December 2013, and quickly began ramping up excavation pace using a muck pump for muck removal in old alluvium. "It's the first time a muck pump has been used here. We've gotten good advance rates, the fastest advance rates in Singapore, in fact. We started our actual excavation at 1 ring a day, then very quickly moved to two, and then by the time we reached rings 50-60, were getting up to four rings per day: The first time that has been done here," said Birch. While the 30m deep tunnel does not pass near existing utilities or building foundations, settlement must still be kept to a minimum and ground conditioning is a factor in that: "The operators know about continued conditioning in front of the head, and that the material must be kept at a certain consistency. We are injecting foam and monitoring the earth pressure sensors continuously. It is imperative that we maintain about 1.6 bar on the top two pressure sensors, the middle is at about 1.8, and the bottom sensors around 2 bar." Contractor GS Engineering is verifying the effect of the machines with surface settlement monitoring.

By February 2014, the TBM had about 670m remaining, with completion expected in April 2014. Once the machine

Singaporean economy projections

Based on Timetric's current forecast of an improving global economic activity along with sustained growth in domestic demand, Singapore's economy is expected to grow in the range of 2.3-3.9 per cent during 2013 and 2014. Timetric expects GDP growth to improve over 2015-2017 and stay in the range of 4.3-4.9 per cent, led by stable domestic and global demand. Despite a moderation in the operating revenue growth by 6.5 per cent in 2012 (14.4 per cent growth in 2011), Singapore's general government budget surplus widened from 4.8 per cent in 2011 to 5.7 per cent of GDP in 2012, as government's operating expenditures fell by 0.6 per cent (SGD 34.8bn) in 2012 against a growth of 6.9 per cent (SGD 35bn) in 2011. However, as development expenditure is growing at a faster pace, from 4.1 per cent in 2011 to 5.9 per cent in 2012 on account of an increase in investment in transport infrastructure, the overall government expenditure increased to SGD 54.4bn during the year, higher than SGD 47.3bn in 2011. The government budget surplus is expected to narrow and stay in the range of 4.8-5 per cent of GDP during 2014 and 2015, owing to an increase in infrastructure, social and healthcare expenditure.

The construction industry is one of the most important industries for Singapore's economy. According to the Singapore Department of Statistics, the industry's value add rose by 7.7 per cent in the first-quarter of 2013, compared with the same period in 2012. The industry accounted for 12.3 per cent of the country's workforce in 2011. In 2012, the construction industry registered a demand for manpower and consequently, employment increased by 46.3 per cent, from 6,700 in the third-quarter of 2011 to 9,800 in the third-quarter of 2012.

Danny Richards
Senior Economist
Timetric

has completed its initial 800m section, it will be stopped in a blind tunnel and dismantled for use on its second tunnel later in 2014. The machine on its second tunnel will be

stopped a few meters shy of the station and dismantled, allowing the station contractor to hand excavate the last metres of tunnel.

C927 Site: Good advance under abrasive conditions

The TBMs at site C927 for CMC were launched in October 2012 and June 2013, respectively. A soil mix block 10m in length (length of shield) x 20m wide was added around the docking area for the TBMs. Excavation began in tough conditions from the outset: "Old alluvium is renowned in Singapore to be particularly abrasive. We use foams and polymers. I've worked for 16 years in Singapore, and this ground is particularly abrasive, with regular interventions every week to change out carbide bits and scrapers. This is generally done every 100 to 150m," said Knight-Hassell.

Ground was particularly challenging around the area of the canal where the ground was sandy and already prone to natural settlement. "When we were going through this area with the first machine, we did experience some settlement, and we are hoping to mitigate any settlement in this area with the second machine."

The first of the CMC machines broke through in October 2013, after having



achieved up to 15m per day. "The machine is well built and it's a very robust design, built to last," said Knight-Hassell. The TBM exited into a 20m wide receiving shaft, abutting the 200m long main station structure. CMC applied ground treatment to allow the TBM to sit at the diaphragm wall, so that crews could hand excavate to meet the TBM head, allowing the TBM to move forward onto the cradle. Both machines must exit into this limited shaft space, which only allows about 5m of room to remove the machine due to struts crossing the shaft area. The first of the two machines was removed and transported to the United States for refurbishment and use on Seattle's North Link project later in 2014. CMC's second machine had approximately 500m of tunnelling left as of February 2014.

C937: Boring through Boulder Fields

The three EPBs at GS Engineering's C937 contract were launched between March and October 2013. Sections of tunnel are located in the Fort Canning Boulder Bed, though as of February 2014 the TBMs were only beginning to touch the outer edges of the formation. Located between 0.5 and 20 m below the surface, the boulders consist of sandstone with quartzite and felsites, and are thought to have been deposited between 0.5 and 1 million years ago in a series of landslides and mudslides. Boulder sizes are predicted to have a minimum of about 0.5m and a maximum of 3m in diameter.

The implications of the boulder field on TBM tunneling are complex: Since the boulder bed has relatively strong boulders located in a clay matrix, the cutting action of the disc cutters on the TBM cutterheads is hindered. Before the pressure required to chip the boulders into fragments is reached, the boulder moves in the clay matrix. When these boulders move, they can bang against other parts of the cutterhead, such as scrapers and bits, and damage them as well. In addition, the boulders and clay matrix have different hardnesses, so that the cutters are exposed to many shock loads in a short time. This reduces the life of the cutter and creates more interventions to replace the cutters. Boring through this boulder field is expected to be a slow ordeal as the TBM must go slow enough to avoid moving the boulders, but still push hard enough to break the boulders. If the boulders will not break, divers must go in front of the cutterhead to manually break up the boulders before the machine can advance.

As of February 2014, the three TBMs had 94m, 270m, and 585m remaining, respectively. The TBMs are expected to



Above: Mixed ground conditions ranging from clay to mudstone, sandstone and boulder fields dictated the use of mixed ground EPBs on many of the tunnels.

hole through between March and October of 2014.

A HOTBED FOR TUNNELLING

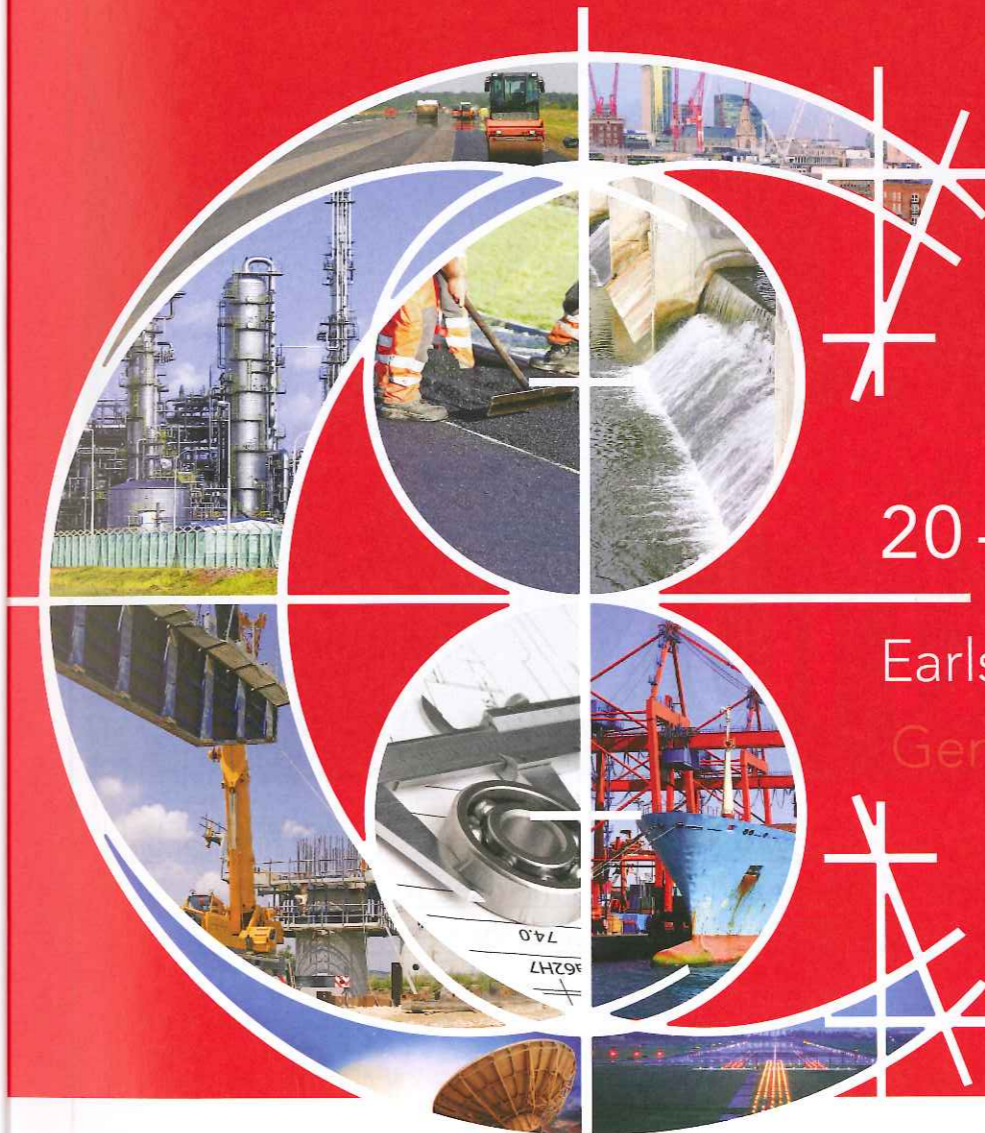
Overall, Singapore is a hotbed for TBM tunnelling worldwide—a place where EPBMs are challenged by abrasive conditions, mixed ground, karstic formations, and settlement issues in a densely populated city-state. While launching an EPBM from a postage stamp size job site with only a small shaft is not ideal, there is often no alternative when extremely rapid development of a metro system is demanded.

With proper pre-planning and well-designed temporary equipment, such as a services umbilical and mucking devices, it is possible to successfully launch machines from such small shafts.

There likely will be a growing number of metro projects which require such launches. Singapore is proving to be a country where methods for safe and efficient small shaft launches are being perfected, and where the EPB tunnelling method is successfully pushing the limits

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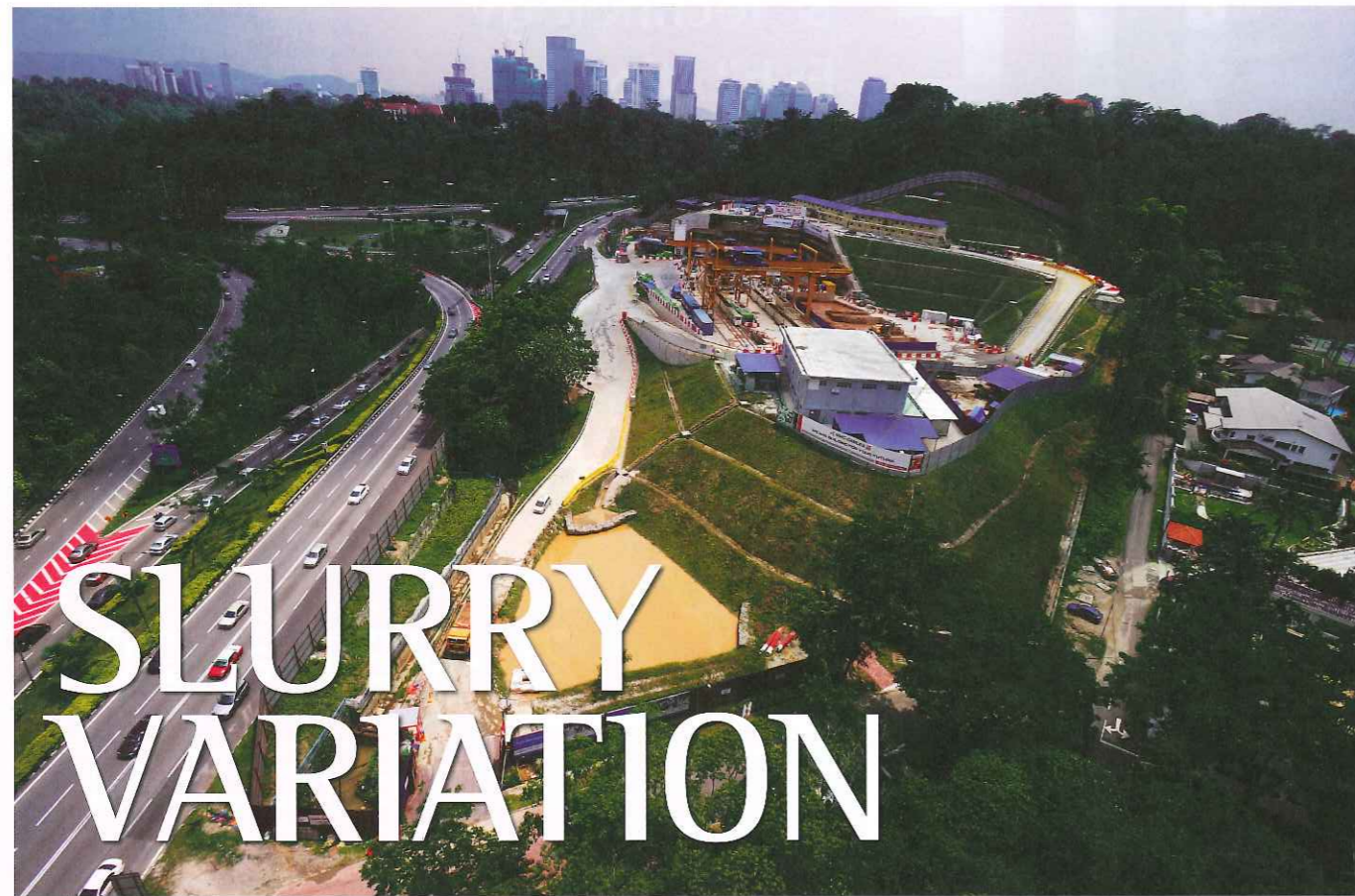
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SLURRY VARIATION

The Klang Valley MRT project recently saw the breakthrough of the world's first variable density slurry TBM. Client MMC-Gamuda JV delves into the need for the system, geology, and experiences on the SMART project that called for a new type of TBM

KLANG VALLEY is home to some seven million people, and in 2020 the forecast increase to 10 million signifies an exponential trend. This translates to about 18M trips a day in the Klang Valley and if these trips are done in private vehicles, all roads in the Klang Valley will be gridlocked through the day. For now the bottlenecks are at most locations in and out of the city centre during peak times, not that it is any consolation to the commuters.

A sustainable solution was needed and a swift implementation strategy had to be put in place to overcome this impasse where the public suffers daily with millions of hours lost each day in traffic jams.

It was decided that mass rail transit (MRT) would be the first of a larger public transport plan put in place by the Government. Aside from the



Gusztav Klados

Gus is head of underground works for MMC-Gamuda. He was also in charge of contract documents preparation

capacity advantages, MRT uses less fuel per capita than road solutions. It is well established that a rail-based public transport such as MRT, light rail transit and monorail or commuter system forms the most effective backbone of a city's public transport system.

Klang Valley has a definite shortfall: a lack of rail based transport coverage compared with most public-transport oriented cities. Klang Valley is seeing unprecedented scale of development and the forecast is still of an upward trend. However, Klang Valley has less than 20km of rail per million population. In



Satpal S Bhogal

Satpal is a project director for MMC-Gamuda and has 43 years of experience in civil engineering projects

this context it would be noteworthy to mention that public transport oriented cities like Singapore, Hong Kong and London have more than 40km of rail per million population.

With a vision to make Kuala Lumpur move up the notch to settle amongst the 20 top most liveable cities in the world, the Government in Malaysia embarked on the first MRT project, not an easy undertaking, especially given the fact that there is no reserved rail corridor in the Masterplan of Kuala Lumpur. Because of this, whatever the chosen alignment, it cannot avoid impacting people and existing structures.

For Klang Valley to function without hitches and glitches in the form of traffic hold ups on the road, at least 50 per cent of all trips need to be on public transport. And the only way to achieve this is to have an efficient, world-class public transport that satisfies the demands and fulfils the needs of the people living in the region.

MRT TIMELINE

Contrary to what detractors say about Klang Valley MRT (KVMRT) - that it was a poorly visualised project and came about as an afterthought, it has been in focal study since 2006. The initial proposal was to have a 43km east-west alignment running from Kota Damansara to Cheras. Then came a proposal from the MMC-Gamuda JV in early 2010 with a more comprehensive plan consisting of three lines of 141km route length, covering the rapidly growing residential, business and commercial hubs in Sg Buloh and Kajang, which are currently not covered by the rail networks. The proposal was adopted by the government, with some modification to the alignment including that dictated by political pressure and strong community lobbyists.

The project received the nod from the government in December 2010 for an initial radial line of 51km linking Sungai Buloh in the north-west to Kajang in the south-east, traversing through the city centre of Kuala Lumpur.

Of this proposed 51km route with 31 stations, the most challenging is the 9.5km underground section traversing through the most densely built part of the city of Kuala Lumpur. Awarded to MMC-Gamuda JV in April 2012, almost half of the underground section requires tunnelling through a tropical karstic limestone, very similar to the terrain that was encountered during the SMART tunnel construction, with some extreme challenges resulting from the ground losses from the collapse of the highly

10

Million will be added to the region's population before the end of the decade

141

Kilometres are planned for the new route

unpredictable karstic features.

In July 2011 it was all systems go with the launch by the Prime Minister of Malaysia and in May 2012, it was the PM who launched the first TBM (which was also the world's first Variable Density TBM).

The rest is history and as of December 2013, the underground and tunnelling works were nearly half way complete. The underground package includes a mined route length of 7.8km, seven underground stations, utilities relocation, portal structures, temporary launch shafts, ventilation shafts, strengthening and stabilising works carried out prior to tunnelling at buildings and structures that are thought to be sensitive, among others.

All resources are put to test in race against time towards achieving the target line completion date for revenue service of July 2017.

GEOLOGICAL CHALLENGES AND TUNNELLING SOLUTIONS

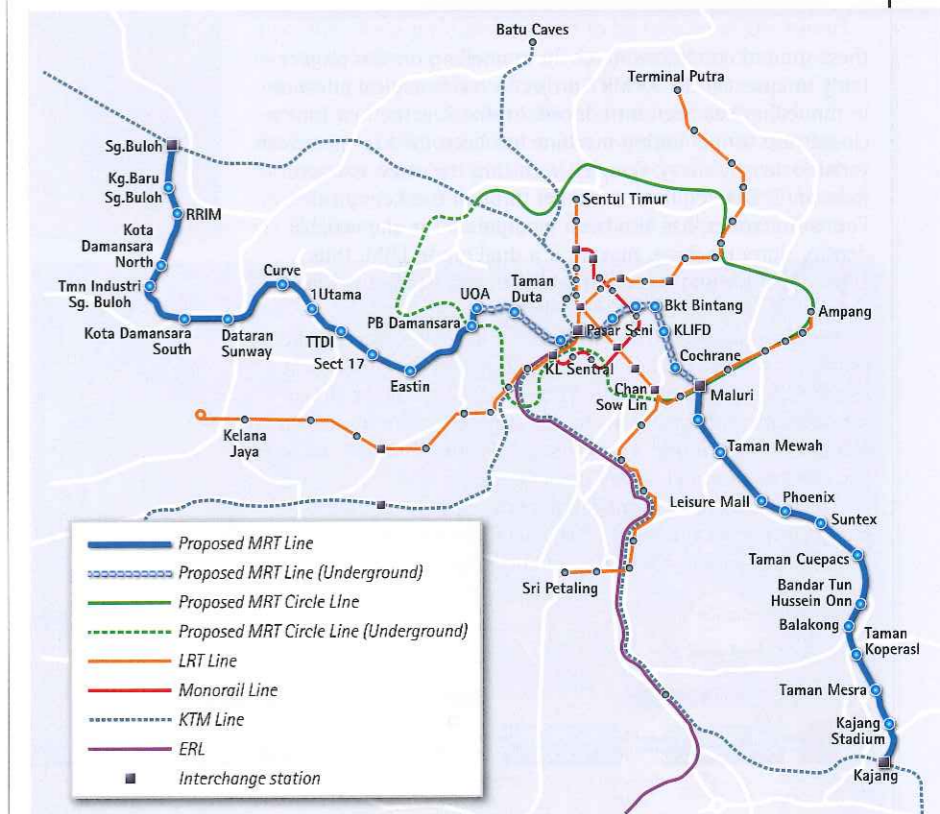
The city of Kuala Lumpur along the KVMRT alignment is generally built on Kenny Hill Formation and Kuala Lumpur Limestone. The Kenny Hill Formation is predominantly sedimentary rocks of interbedded sandstone/quartzite and shales/phyllite that have been subjected to some regional metamorphism. From an engineering perspective, the Kenny Hill formation is predictable and hence easily managed during design and construction.

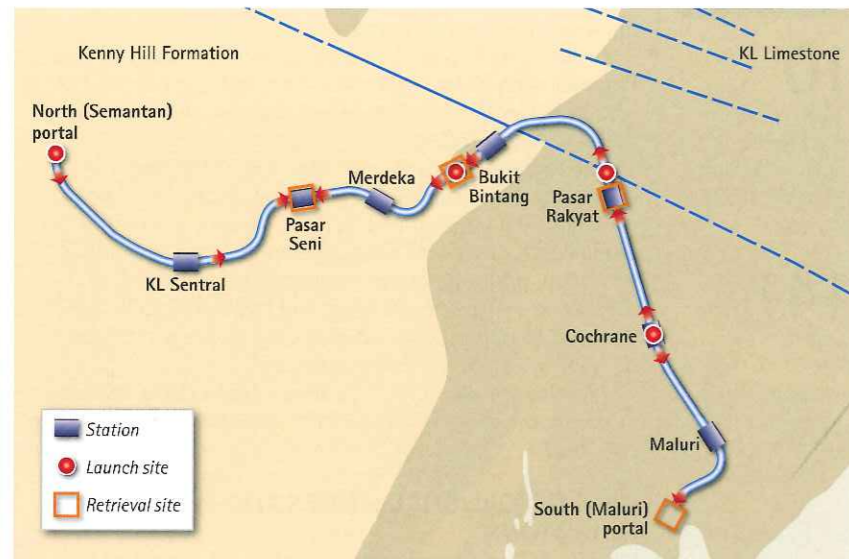
However, Kuala Lumpur limestone, which is classified as 'extreme karst' (5 on a scale of 1 - 5), has intricate three-dimensional networks of solution channels, steep sided crevices and highly irregular rockhead, overlain with soft soils. The high groundwater table, overlying soft soils - often mine tailings - and the interconnected solution channels in limestone pose great challenges in trying to keep the tunnel excavation face supported without any incidence of sinkholes and blowouts.

The geological challenges involved in tunnelling through

Left: Development is booming on the city's outskirts

Below: The proposed network and current construction





Above: Tunnel drives through the Kenny Hill formation and limestone

Left: The tunnel portal worksite

Below: Tunnel drive sequences

these ground conditions make the tunnelling on this project fairly unique. On the KVMRT project a technological advance in tunnelling has been introduced, in that it is the first time a closed face tunnel boring machine has been used to mine with variable density slurry. Coupled with this, the screw extractor from an EPBM, required to tunnel through the Kenny Hill Formation zones, has also been incorporated in the variable density slurry machine, making it a dual mode TBM, thus allowing tunnelling through middle section located half in Kenny Hill and half in karstic limestone.

Heading the major risks, in this highly challenging KVMRT project, is the risk related to the geology and the groundwater levels along the tunnel route. With almost half of the 9.5km tunnelling length sitting in the tropical karstic limestone, the tough task was to find a tunnelling solution to match the high risk construction and satisfy the insurers.

The design of the tunnel alignment itself is a complex matter involving a number of key decisions on the optimal route through a labyrinth of high end properties, the TBM

and future operation considerations, among others. For these crucial decisions, good knowledge of the ground conditions through which the tunnel will be constructed and the groundwater levels along the tunnel route is critical. Keeping the tunnel as shallow as possible to align with the end user requirements introduces another challenge of tunnelling through a mixed face, rock and soft overlying soil.

MINIMISING SUBSIDENCE THROUGH TBM CHOICE

In order to comply with the stringent tolerances on subsidence and safety to public, closed face TBMs were chosen. For KVMRT, 10 TBMs will be used to mine 7.8km twin bore tunnels to meet the tight programme. Five sets of twin tunnel drives (10 in total) were found appropriate to manage the risk of interfacing with station construction, as both have to be constructed simultaneously to meet the programme.

Blow outs in limestone occur when the high face support pressure from the slurry intersects a solution feature that is connected to the overburden above. Sinkholes on the other hand happen when there is a loss in face support pressure due to major loss of slurry into the cavities. Both incidents rely heavily on managing the delicate balance between the face support pressure from the machine and the active ground and water pressure.

It is clear that the risk related to karst would remain the biggest challenge to the tunnelling works in Kuala Lumpur limestone and the use of a modified slurry shield TBM that is capable of preventing the formation of sinkholes and blowouts during tunnelling would be ideal for this formation. Armed with the experience and exposure of having tunnelled in karstic limestone while building the SMART tunnel, MMC-Gamuda JV, the wholly Malaysian joint venture entity took upon itself to expand its capacity in terms of building on its human capital in the tunnelling and underground works.

When tunnelling for SMART, despite the use of slurry TBMs, the project experienced sinkholes, settlement and subsidence that caused delays. The

engineers who were involved in building the SMART tunnel knew they had to expand their knowledge and expertise to ensure that the next tunnel to be excavated in the karst faces fewer or no problems.

MMC-Gamuda JV invested in R&D and worked with Herrenknecht to develop an improved slurry machine that would tackle face pressure losses in a karstic limestone environment.

THE TWIN MODE VARIABLE DENSITY MACHINE

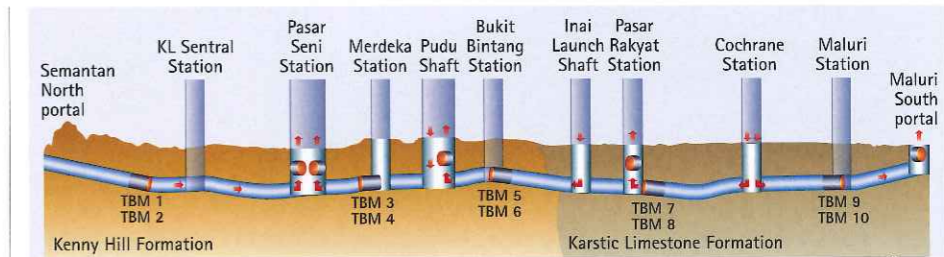
Slurry TBMs are normally used in high permeability and or highly variable and unpredictable formations such as in the karstic limestone, which is riddled with fissures and cavities. Hitting a cavity or a fissure which has not showed up in any of the geological surveys can be a debilitating affair – for the contractor as well as the public. Experience shows that in karst conditions the spoil generated by the cutterhead does not provide a seal in a screw conveyor of an EPB TBM even with extensive spoil conditioning and therefore cannot keep face support pressure and prevent groundwater



drawdown. EPB machines are not the right choice for this environment.

The slurry TBM can normally deal with such unexpected cavities if the cavities are filled by washed in soil which prevents large quantities of slurry loss to the karst system.

On the SMART project, while the low density bentonite slurry based face support did work while traversing minor fissures and filled cavities encountered in the karst, there were incidences of surprise sinkholes and blowouts and there had to be a much more sophisticated slurry machine to deal with this problem. When the TBM hits an only partly filled karst cavity, large fissures in the rock or a very loose overburden soil pocket, there is a tendency for the low density (1.1t/m³) and therefore low



Above: Stations on the alignment within the varying geology

Below, both: The breakthrough of the world's first variable density machine

viscosity bentonite slurry to escape into the karst channels or to the surface through the connecting fissures and we would have a blowout. The resulting instant loss of face support pressure would then cause sinkhole formation.

To counteract this instant loss in face pressure when a blowout occurs, the concept of variable density bentonite slurry system was developed. The underlying concept is to increase the density (from 1.1 t/m³ up to 1.6 t/m³ or more) of the bentonite slurry when traversing through "suspicious" ground, by adjusting the thickness (increasing the viscosity) of the mixture with limestone powder.

The variable density machine works on a principle where the density of fresh bentonite slurry pumped into the excavation chamber can be varied – increased – according to the ground condition. Normal slurry machines do not have this capability and hence this function makes the TBM special.

MMC-Gamuda JV project manager Gus Klados, who was previously the project manager for SMART and has been involved in the variable density development, explains that the conventional slurry TBM relies on bentonite slurry, which supports the tunnel face by forming a thin, impermeable bentonite layer on the soil/rock face and the pressure of the bentonite slurry itself than acts on this 'film' to support the tunnel face in front of the TBM cutterhead in the excavation chamber. During the excavation process this film is scraped off by the rotating cutterhead but it immediately re-forms behind the scrapers or cutter disks. The bentonite film makes it possible for a pressurised shield to be created at the tunnel face to balance the pressures of the groundwater and loose soil acting on the other side of the shield. The pressure of the bentonite slurry is closely regulated by an air bubble behind the hanging bulkhead between the excavation chamber and the working chamber. In case of the standard slurry machine the pressure is transferred to the front, to the working chamber via the opening of the hanging bulkhead in the invert where





crusher and the rake is located.

The variable density TBM came in at a time of critical need – as most inventions do – and is the first in the world.

In the case of the variable density TBM there are some key differences. The increased, higher density slurry may not easily be pumped out through in the usual way, a different discharge system is needed. There is no connection around the screw conveyor to transfer the pressure of the working chamber air bubble in the variable density machine therefore the working chamber is connected to the excavation chamber by a pipe, transferring the bentonite slurry and its pressure into the working chamber in front so that the face support pressure is always maintained at the required level. There is also a pipe feed from the surface for high density slurry which has direct access into the excavation chamber, bypassing the slurry chamber, to pump in high density slurry when the need arises to increase the density.

The variable density machine can be operated in the classical Slurry TBM mode incorporating an air bubble system for face pressure control and using the low density slurry to form the bentonite “cake” on the face or in a variable density mode when the bentonite “cake” does not form and the support is provided by the friction of the high density slurry penetrating the soil voids as well as in the full EPB mode.

CAPABILITY

The machine achieves a system that can transform from a slurry face support into an earth pressure face support in the tunnel without any need for mechanical modification in the excavation chamber and little work behind in the gantry/ tunnel area. In this context, the variable density-TBM is effectively a combination of EPB and slurry machine. To convert the variable density TBM to work in full EPB mode

Above:
Celebrating the
breakthrough

requires removal of the slurryfier box and adding a conveyor belt in the trailer to facilitate the solid spoil removal. For KVMRT, the machines were specified to make this conversion relatively easy. Most elements of the conveyor system are already delivered with the trailers. For the conversion there is no need of the working chamber interventions.

The transfer between the low density and high density slurry operational modes can be done easily just by injecting fines through a pipe feed from the surface bringing in high density slurry. If and when pumping the slurry through the screw conveyor becomes difficult, the screw must be operated to bring the loaded slurry into the slurryfier box where it is diluted by fresh bentonite slurry to become pumpable by the usual means to the separation plant. The high density slurry line may be also used to condition spoil in the working chamber.

PROGRESS

As of December 2013, five variable density TBMs are in the ground with the first variable density TBM expected to breakthrough in January 2014. Two of the four EPB-TBMs are tunnelling the north drives in the Kenny Hill section. The last of the TBMs are planned to complete boring in May 2015

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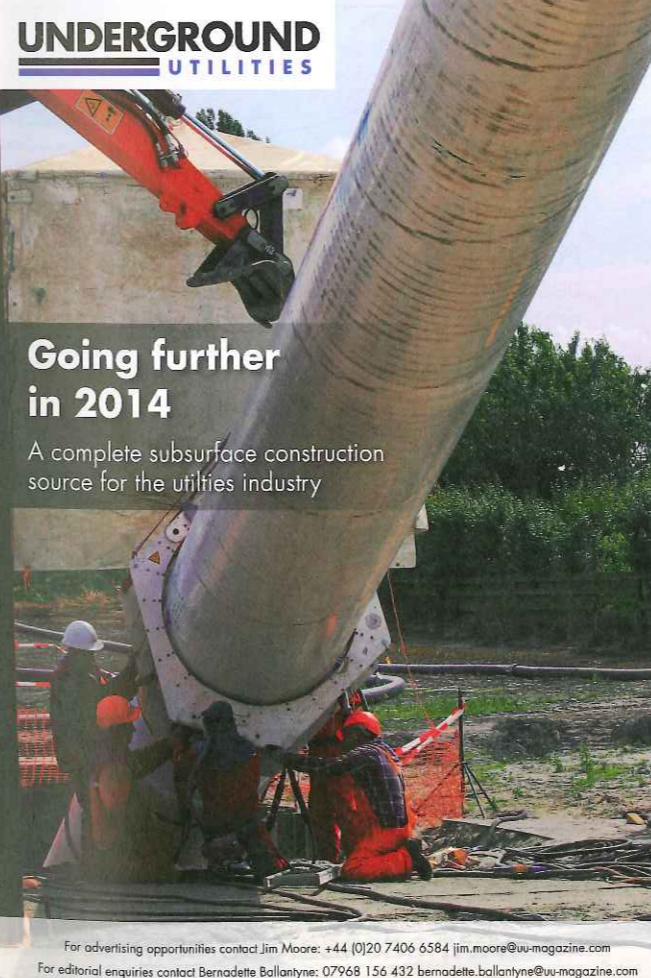
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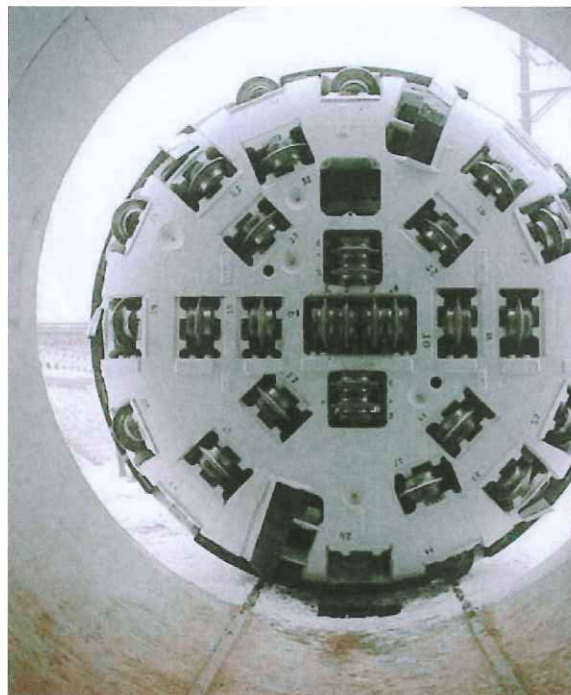


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The growing popularity of sprayed waterproofing membranes for use in NATM/SEM/SCL tunnels has again been highlighted on the Buenos Aires Metro, the mass transit system that serves the Argentinean capital. Stirling Lloyd's development director, Mike Harper outlines how its Integritank HF membrane met the stern waterproofing challenge of this major South American project

Mike Harper

Mike Harper is development director for Stirling Lloyd, and specialises in transport infrastructure



THE BUENOS Aires metro, known locally as 'el subte' is an extensive underground metro system consisting of six lines. One of them, Line B, has recently been extended to include additional stations and at the end of the line is a cavernous, four track wide parking garage for the metro trains. Excavated by NATM, this huge space is 18m in diameter and 11m high, and its tunnel lining comprises a cast in-situ invert section and an arch and crown upper half lined with sprayed concrete for both the primary and secondary linings. The tunnel sits 10-15m below the water table.

SPRAYED PROTECTION FOR NEW BUENOS AIRES METRO

Southland Contracting

Southland Contracting, Inc. and Mole Constructors would like to congratulate all of the people associated with the Jollyville Transmission Main Tunnel in Austin Texas for the completion of 6.5 miles of tunnel and 955' of vertical shaft without a lost time accident.

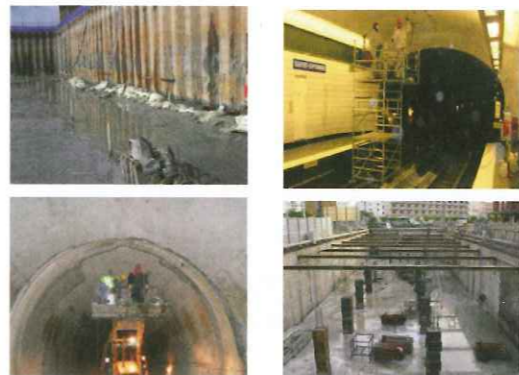
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A second new structure, the workshop, which utilised a similar construction method, is approximately 12m wide and 6.4m high and lies around 20m below the water table. With both spaces therefore significantly below the water table and the ground conditions in Buenos Aires very permeable, the requirement from the client, Sbase, was for a higher level of water tightness than had been achieved in previous projects.

THE REQUIREMENTS

The design of both structures incorporated lattice girders and temporary sprayed concrete as the ground support primary lining. Due to a short construction programme requiring a rapid build speed, the design was for permanent unreinforced sprayed concrete as the secondary and final lining from axis to crown and cast in place concrete in the invert.

To facilitate the use of sprayed concrete as the secondary lining, Integritank HF seamless sprayed waterproofing was specified as this forms a strong bond to both the primary and secondary linings.

Successfully spraying on to a sheet system is very difficult and so they are not commonly used where sprayed concrete secondary linings are utilised.

In common with all NATM constructed tunnels, the waterproofing membrane would not be accessible after the secondary lining was installed. In addition, due to the permeable ground and the location of the structures below the water table, the ground was to be de-watered locally. This meant that if a system was installed that contained defects they would not become apparent until after the secondary lining had been installed and the de-watering pumps switched off.

20

The size of the aggregates used in the primary lining of the tunnel, according to the local design

Consequently Benito Roggio, the main contractor, required a sprayed waterproofing membrane that could be tested in-situ after it had been installed but before the secondary lining was applied, to prove that a continuous, defect-free waterproofing installation had been achieved.

Whilst there is an expectation in tunnelling that tunnels will leak to some degree whatever you do, Sbase were adamant that the workshop cavern in particular needed to be as dry as possible. The workshop cavern was also the deepest structure on the site and was subject to the greatest water ingress during construction with the ground remaining wet despite de-watering.

THE CHOSEN SYSTEM

Whilst sprayed membranes have been extensively used for many years on various civil engineering projects including immersed tube and cut and cover tunnels, the Integritank HF system has been specifically designed for incorporation between the primary and secondary concrete linings in NATM / SEM / SCL tunnels. It was selected for use following presentations not only to Sbase and Benito Roggio but also after trial panels had been sprayed where the membrane's waterproofing quality and ability to be tested in-situ were amply demonstrated.

The trial also showed the system's speed of application and cure, which would aid contract progression and facilitate the work of other trades.

ON-SITE

Once awarded the waterproofing contract Stirling Lloyd worked closely with Benito Roggio to agree the waterproofing details prior to construction and a local contractor was trained in the application and use of Integritank HF by Stirling Lloyd technical staff.

The primary lining of the tunnel was a locally designed sprayed concrete mix containing 20mm aggregates. Consequently, this 'as shot' sprayed concrete surface was very rough and not suitable for the application of a spray applied waterproofing system. A render layer was therefore applied to

"Successfully spraying on to a sheet membrane is difficult and so they are not commonly used where secondary SCLs are utilised"



Above: Sprayed membrane application

Below: View from the bottom of the Lee Tunnel pumping shaft in the UK, another site making use of Integritank

the concrete primary lining which was trowel finished to close up surface voids and remove any projections.

Though the ground was being de-watered, local conditions meant that damp spots in the primary lining were common at the time of the waterproofing application, requiring the Integritank HF system to cope with these conditions.

The first part of the Integritank HF system is the HF Primer. This not only generated a high bond strength between the concrete and the membrane, in excess of 0.5MPa, as measured by the tensile adhesion tests conducted which are part of the unique Quality Assurance Programme carried out on site by Stirling Lloyd, but also allowed the system to be applied to concrete that was damp.

The primer changes from white to clear as it cures, providing visual confirmation that membrane application could begin.

Once the primer had cured, which took approximately twenty minutes, the Integritank HF was applied in two, 1.5mm coats of highly contrasting colours – the first being yellow and the second white. The yellow colour was used because it contrasted starkly with the concrete and would show up any potential defects well under artificial lighting, enabling the sprayers to ensure that all areas were adequately covered and any defects easily identified. Once this coat had cured, typically in thirty minutes on this project, the white second coat was applied. Two coats help ensure complete coverage to the required specification. Thickness was measured constantly during application by 'wet film dipping' by a quality assurance technician who guided the sprayer; further ensuring the correct thickness was applied. The thickness of any waterproofing membrane is important as it is directly related to the waterproofing capability of the membrane. Therefore controlling thickness to ensure optimum performance

is essential to successful sprayed waterproofing applications.

Spraying was carried out by trained operatives rather than using robotic spraying equipment. Robots cannot see if they have missed an area or measure thickness and as tunnel substrates are uneven the ability to control the quality of the membrane application by an operator at the work face is essential in the author's opinion.

FLEXIBLE PROGRAMME

To meet the challenge of the rapid





Above: Water-proofing application in stages

build programme for both caverns, the waterproofing was scheduled to be installed in phases. Traditional sheet waterproofing usually requires installation in one continuous process which can be restrictive to other works, particularly in a linear tunnel application as they wait for sections to cure.

Utilising the Integritank HF sprayed membrane enabled the waterproofing to be applied in phases. This was possible because not only was the membrane fully bonded to the primary lining so that it could be left securely in place until the secondary lining was ready to be applied but also because Integritank HF bonds to itself, irrespective of the length of time between applications. Application could therefore be discontinuous with the untreated areas between the coated areas being sprayed at a time more convenient to other trades. In fact, waterproofing was carried out in multiple locations across both structures to fit the requirements of the construction sequence, with the

"Waterproofing should be capable of being tested in-situ before secondary concrete is applied"

different areas of application being joined seamlessly to form a continuous membrane. The rapid cure meant that there was no requirement for extended cure times before the secondary lining could be installed allowing the contact to progress rapidly. In wet ground conditions, such as those on this project, it is preferable to install the secondary lining close behind the waterproofing.

Another important lesson in the quest for complete water tightness is

the need for close attention to detailing. Major projects such as the Buenos Aires Metro require detailing around complex and vulnerable interfaces such as where tunnels intersect with shafts or other existing structures. The uncertainty of lapped joints and multiple seaming, common at interfaces with sheet membranes, is removed by the use of sprayed membrane technology which is ideal for complex metro tunnel geometries because it follows whatever substrate shape is present. If it can be built in concrete it can be waterproofed seamlessly with Integritank HF as long as all detailing is pre-planned and, wherever possible, ad-hoc detailing avoided.

QUALITATIVE TESTING

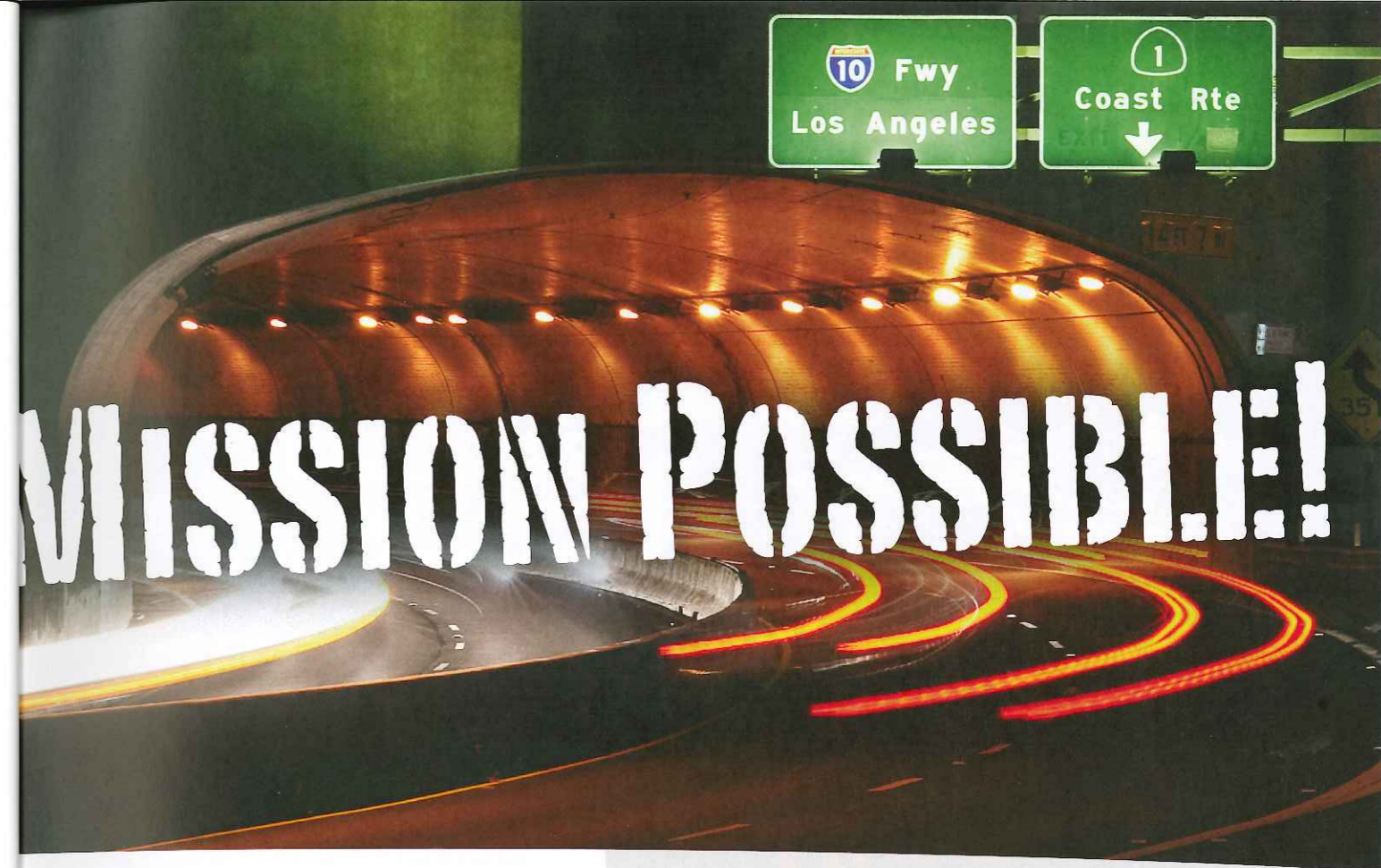
To confirm high performance, effective waterproofing had been achieved, the membrane was tested qualitatively after installation by electrical integrity testing, known as holiday testing, which provides reliable results quickly and does not damage the membrane. The membrane surface was divided up into panels 500mm wide using a marker. The panels were then numbered and tested using a 'holiday tester' with a 600mm detecting head. This ensured that every square metre of the surface membrane was tested and if any defects, even of pinhole size, were found they were marked and repaired prior to the secondary concrete being applied.

Many waterproofing systems do not show up inadequacies during construction because de-watering of the ground is underway and the water table does not return to its position until after the secondary lining is in place. Leaks can become apparent at this point but it is often too late to adequately treat them, hence the secondary measures often built into the construction phase for traditional waterproofing as a fall back.

Engineers should not, however, be having to make these compromises. The waterproofing should be capable of being tested in-situ before the secondary concrete is applied, even when water is not present. The holiday integrity testing used when Integritank HF is installed does exactly that, providing a new level of confidence that the membrane is completely defect free. On this metro project, this essential part of the waterproofing application was carried out in conjunction with the client and the main contractor, with each area being signed off and handed back to the main contractor as waterproof.

CONCLUSION

In total 20,000m² of Integritank HF was successfully installed in the two caverns of Buenos Aires Metro Line B. Both the contractor's requirement for rapid installation, and the client's for a high degree of water tightness were met



Starting on June 22, professionals in the tunneling and underground construction arena will come together and share information and expertise at the 2014 North American Tunneling Conference held at the J.W. Marriott in Los Angeles. Attendees will include owners, equipment and service providers, designers, consultants, engineers, contractors and managers.

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Promotion



Institutional support



As BIM plays bigger roles in tunnelling projects, engineering nous is still king, say clients. Report by Patrick Reynolds

TUNNEL PROJECTS are starting to adopt Building Information Modelling (BIM) to use the greater computing power today to squeeze out, early on, the risks to time and cost. The move comes amidst BIM's wider adoption in the construction sector, and the UK Government pushing for it across most infrastructure and building procurement within a few years.

www.tunnelonline.info

Interest in BIM has been sparked by such advocacy, and the possibilities for greater efficiency in civil engineering. But, as has been found in the building sector, where it has been in use for some time, there is uncertainty and debate around BIM.

Questions rise over what it is, how it works, and who manages it.

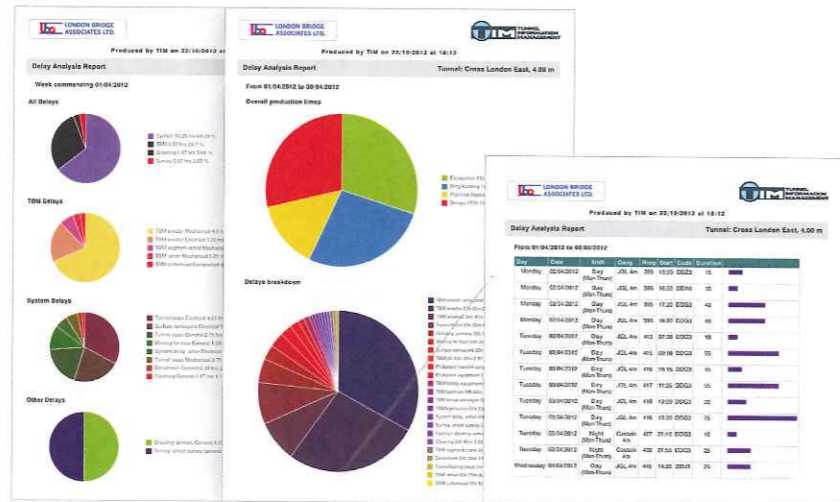
The common concept is that BIM is mostly about building 3D models, but they fit in a bigger field of project information management. Also, views differ about how it all works, and how to set down the IT regime.

Advocates of the long view see information management at the service of asset management, and so would like clients to set down an agenda drawn up by their operation and maintenance teams, in light of whole life costs and performance. However, as BIM is only starting to make inroads in the infrastructure sector; the focus – even for clients – is still around those leading on design and construction. It is still early days.

BIM'S BUZZ

But the buzz about BIM is rising in intensity, and it may seem that construction is being drawn into the IT world. However, it may come as a welcome surprise to hear the common message from those in charge of BIM – or, rather, information management – on two of the world's largest tunnelling projects, Crossrail in the United Kingdom, and the Fehmarnbelt Fixed Link project between Denmark and Germany. They stress that engineering knowledge and experience always comes first, not IT; and, that BIM is an 'enabling' tool only.

They underline the point by emphasising that there is no single way



Above and below: Tunnel Information Management (TIM) is making headway in the industry, see box overleaf

of using BIM, no off-the-shelf approach or black box. Choices are made job by job about managing information.

Therefore, it is down to experienced engineers and project managers, holding ultimate responsibility. BIM is the servant, and not the master.

CROSSRAIL - BUILDING INFORMATION MODELLING ON EUROPE'S LARGEST INFRASTRUCTURE PROJECT

Crossrail recently gained more recognition of its work with BIM by receiving the 2013 British Construction Industry Award for the civil engineering category.

Yet, the development company Crossrail's head of technical information, Malcolm Taylor, says BIM is only a support for the engineering effort.

The cross-London rail scheme may be a BIM "environment", says Taylor, but he emphasises that it is not a BIM project: it is a transport project. Business needs must drive the use of IT and not the other way round.

"Only create information and models to help make decisions," he adds.

Taylor puts forward that BIM is simply a way to seamlessly integrate information, otherwise knowledge is lost at each handover step in the supply chain. He notes however that contracts do not feature BIM as a contractual term.

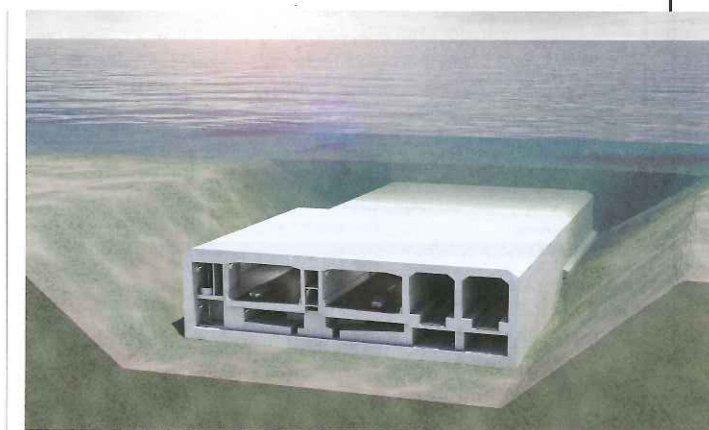
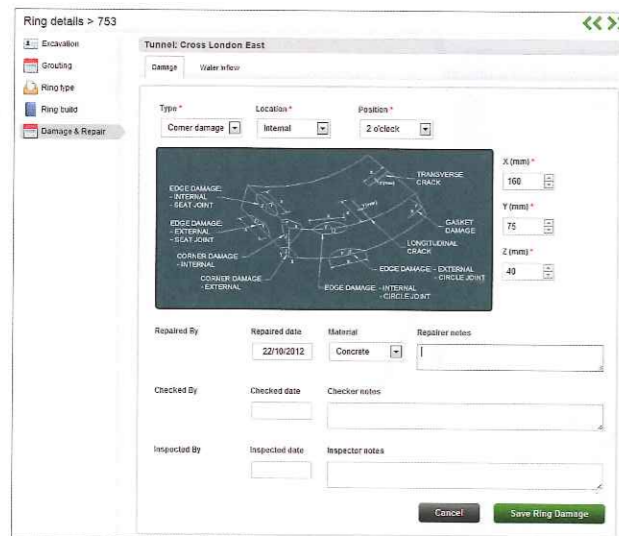
Crossrail is managing the project's development, and hence the use of BIM. It has the designs and plans of the supply chain all nestling and fitting together in the same spatial environment.

Virtually assembling the packages and files helps to show their fit – or not, and then changes can be made early.

On Crossrail, the information management systems are founded on Bentley systems, including use of the IT firm's eB relational database at the heart of BIM web. The project uses the Uniclass 2 classification system, dedicated for structuring information in the construction sector.

To minimise IT problems and potential erosion of data, Crossrail also requires its entire supply chain to be able to deliver information in the same format. Other IT systems, such as those of Autodesk, for example, can be used but data must be sent in a readable format.

Bentley also works with CRL in providing BIM training through a dedicated "academy".



Above and left: Crossrail and Fehmarnbelt are two projects that have made use of BIM, to some extent

everybody's interest.

The virtual assembly is, basically, a Level 2 approach to BIM. The next stage up, Level 3, would be a single model only with integrated, interoperable data, though it has yet to be fully defined, he says.

With 3D being such a focus, the project also features work at 4D level – where contractors marry their sections of the 3D model to construction programmes. As scheduling of works impacts neighbouring sections, but each supplier holds their own information, CRL has a dedicated border oversight team for 4D.

Commenting on the ability to test alternative options Taylor says, "I think the 4D area has given the greatest efficiencies."

The project's BIM muscle, at present, manages approximately 1.275 million CAD model files, a little over a million e-documents, and 'publishes' up to about 1,000 drawings (2D slices/renditions of the compiled 3D model) at peak – at the end of every week, and month.

Having so much data to hold and process, the IT system needs to have enough capacity and power to strategically anticipate the needs of the next steps in the project development cycle. A major 'health check' was carried out in 2010, a smaller one in 2013, another is planned for this year, and there is a potential large check earmarked for about 2015-16.

Capacity and communication

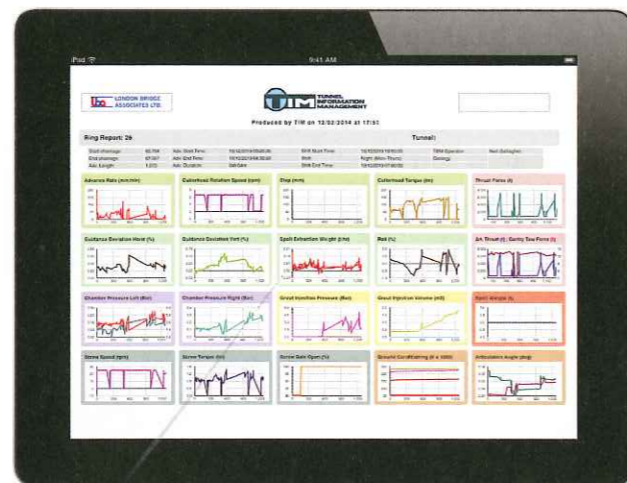
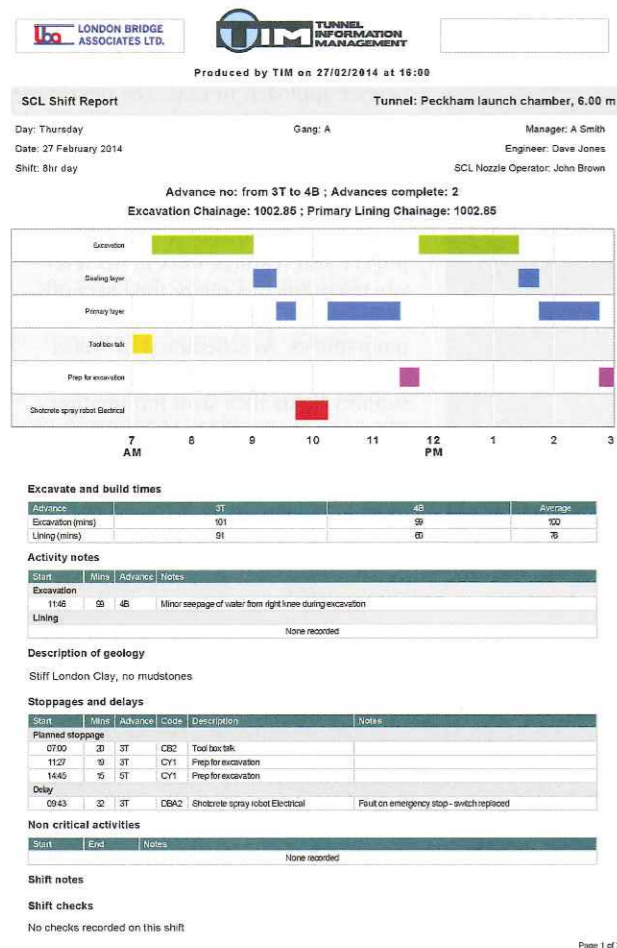
The storage capacity needed currently is about 7.5 to 8TB, and a close eye is kept on needs on an ongoing basis with upgrades done on a "needs" basis, but the total volume is expected to be ten times as much by the end of the job.

Crossrail is a huge one-off project with a major bespoke IT system, there are activities on multiple sites by

Designers and contractors tending to their own parts of the overall virtual assembly, and are given limited permits for access.

To keep the virtual assembly – what Taylor calls the 'single source of truth' – up to date, CRL controls how and when anyone can make changes to their own submitted data. Like a library, they have to "borrow" and then "return" the sections. In the meantime, everyone else is alerted through a change of the section's status to "work-in-progress".

No one gets to see inside another's files, says Taylor – at least not without due process, approvals and it being in



All: Tunnel Information Management (TIM) display mockups courtesy of LBA

multiple parties, and through it all are large flows of information. In this scenario, soft skills are vital, says Taylor. BIM demands it.

"It is very much about people working together," he says. "Communication and team skills are critically important. You can have IT/CAD, but you need team and collaborative behaviours – it sounds rather soft but is absolutely the case."

"Clarity of communication is underneath all of this," he says of applying BIM. "Basic project management."

Perhaps, then, it is 'Project Information Management' as Taylor has come to prefer over simply information management which has heavily infers IT. Or, PIM rather than BIM.

FEHMARNBELT IMMERSSED FIXED LINK PROJECT - INTERNATIONAL BIM

The Fehmarnbelt immersed tube project is at a much earlier stage in the development cycle than Crossrail with procurement of the design and build civils package for the 17.6km long Danish-German road and rail scheme underway.

In Denmark, design engineer Lasse Vester has been responsible for guiding

the implementation of BIM so far for the client, Femern. He says that what comes before, and underlies, BIM is strategic information management – and even that is only in support of engineering through project management with effective collaboration and communication.

"We are not, simply by the use of 3D, making anything better – the basis is still engineering," says Vester.

"The 3D enables you to utilise engineering experience at a much earlier stage," he adds. "BIM is an enabling factor."

The project has software systems including those for models, document management, GIS, risk, quality, and costs.

The client's contract documents refer to BIM in the context of 3D object-based models holding project information. A CAD manual was produced to specify how models are to be developed and their content. It also has rules on data files, and for both exchange formats and scenarios.

But, Vester says, "we recognise that BIM is more than just the building models themselves – it is about the entire information management on the project. The framework must govern how the management of documents and drawing/model, respectively, is set up, and how the systems collaborate across interfaces."

Femern decided to use BIM – or a greater approach to data and information management – during development of the

TIM in a BIM world

For two years, an information management system has been supporting performance on another large tunnelling job in London: the National Grid Power Tunnels Project. The Tunnel Information Management (TIM) system, provided by London Bridge Associates, is web-based and taps live data for contractor Costain-Skanska to allow engineers and managers to analyse metrics.

The details could form a BIM database, notes LBA.

While the major cable tunnels project involves mainly TBM drives, LBA is looking to develop a TIM service for Costain and its JV partner, Laing O'Rourke, to help work on the SCL tunnels of another project – London Underground's Bond Street Station Upgrade. Further ahead, TIM could find use in projects with drill and blast excavation, pipejacking or piling, notes LBA.

The TIM service gathers the key digital data on a project's live construction activities.

Shift report gets completed on an ongoing basis. The data can be scoured by engineers and managers checking online through secure browser links, and by receiving regular PDF reports – by time (shift, weekly, monthly) or distance (for example, per ring, and per 100 rings for handover data). Metrics are shown as data tables or graphics.

Compiled data from TBM drives, for example, can include details and analyses on:

- Production based on time periods, actual progress versus planned, cycle times, gang comparisons, stoppages, and delay analysis;
- Quality, based on alignment, ring build, segment identification, segment damage and repair, grout quantities and testing, etc;
- Consumables, such as tailseal and main bearing grease to warn of under/over use;
- Geology;
- Inspections.

A number of TBMs are employed on the cable tunnels project, which involves approximately 32km of main tunnels. The TBMs

are: a 4m i.d. Herrenknecht EPBM; a 3m i.d. Caterpillar (Lovat) convertible open/closed mode TBM; and, a 4m i.d. TES open shield. Each machine has a wi-fi installation connected to the Internet via the tunnel comms cable, which enables shift engineers to record data at the shield.

The TIM system can take other data from elsewhere on the project, such as segment manufacture information. Photographs can be uploaded too.

Ken Spiby is a director with LBA, and has 25 years tunnelling experience. He says of the TIM service: "It provides the data and analysis that I would want in running a project."

His enthusiasm spearheaded the design and specification of TIM before its first application, on the cable tunnels project, starting in January 2012. He also supervises implementation and customer support. The IT side of the system was developed, and is maintained, by The Commercial Application Co which also owns TIM; LBA has exclusive re-seller rights.

TIM is modular, the standard unit covering production management, while others include: TBM data; quality; consumables; resources; ring manufacturing; and, large screen displays. There are also alert triggers, ranging from problems to reminders. Also, customers decide on activity codes for the data.

Staff permissions (read, write, edit) are matched to secure online access details (username, password), and it is all managed during the project by an "administrator" – a staff member with that extra duty, and who also trains others.

Access is by any internet-connected computer and most devices, including iPads and mobile phones. Mobile apps could be developed.

The volume and speed of data gathering has been leading to greater transparency, and tighter team communications, Spiby notes.

He says: "If retained by the client, asset information can be accessed at any time and TIM, therefore, becomes a BIM database. This could be linked to the project BIM model to provide easy access from a single front end to all construction, maintenance, and operation information."

tender documents in the fall of 2012. Like Crossrail, though, there is no BIM 'unit', as such. This is because it is an approach that suffices the full projects.

On Fehmarnbelt, annual workshops were conducted for key people on different contracts, and also the project support team, to prepare for the BIM approach. The work set down the BIM strategy and vision, and action plans – such as producing the CAD manual.

For the four main civils D&B packages, contractors are to deliver 3D designs instead of only 2D, which "requires the designers to raise the level of information at a very early stage of the design development," says Vester.

He adds that software choices are left to contractors, so long as compulsory exchange formats are in place. Also, as there is no BIM template, there are open possibilities how contractors might develop their models within the bounds set, ensuring a virtual assembly is created 'which would ultimately benefit the project as a whole' – and, therefore, the owner which will be the end-user of the combined project information model.

Vester echoes Taylor's view that BIM choices are made project by project, and adds that it is merely a way to highlight and check the control of information processes people are already using.

The result is earlier designs and tighter project management. But, he notes that the new approach can mean the challenge of change for people, and that must be appreciated and worked with to get to the greater, longer-term benefits.

BUILDING INFORMATION MODELLING - AN OUTLOOK FOR THE INDUSTRY

BIM is not a one-size-fits-all approach from the IT world, then, and that might fit especially well in the infrastructure sector where the uniqueness of projects has consequent demands on how to manage information effectively and efficiently.

If BIM is not a new IT onslaught, then perhaps it is simply the next step in keeping data and information neat and tight; the tail will not be wagging the dog as the expression goes.

Engineering nous rules, as ever

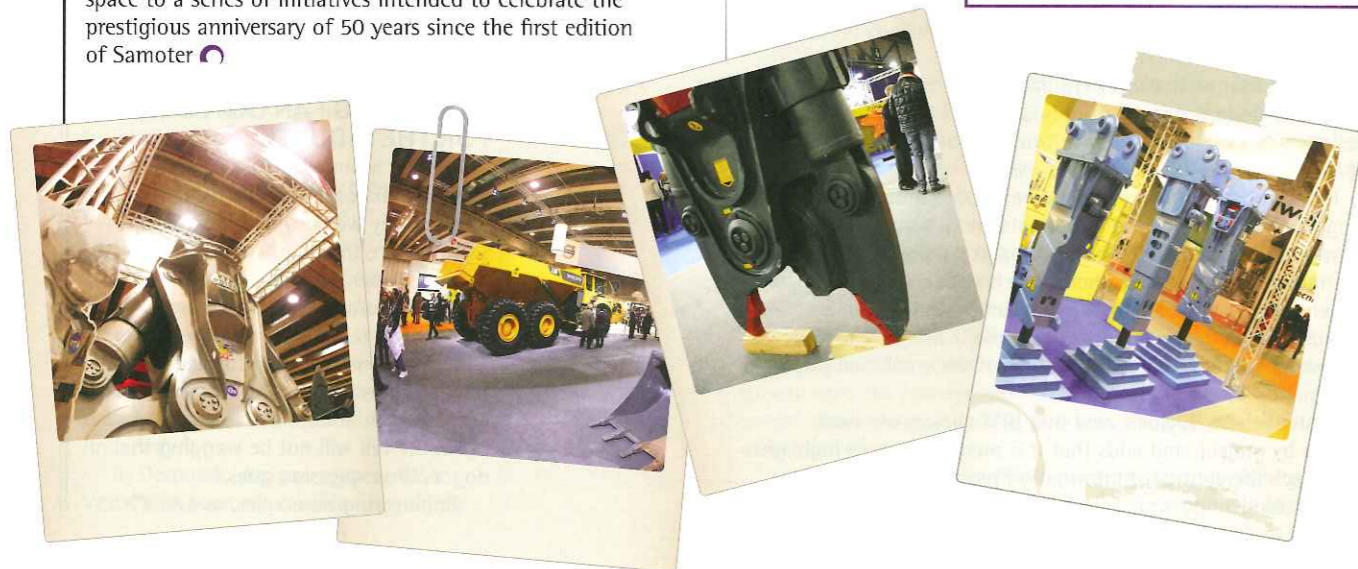
SAMOTER

2014

SAMOTER THE Triennial International Earth Moving, Site and Building Industry Exhibition, celebrates its 29th edition this year. In 2011, the exhibition attracted 98,000 visitors and more than 900 exhibitors (of which almost 30 percent international).

The 2014 edition will see Samoter pursue its commitment to broader environmental attention by expanding its work to improve awareness in the building industry world as regards new prospects for sustainable sites and constructions. Against this background, the focus of the next edition will be "sustainability", a theme that will characterise the entire event through convention initiatives, analysis and training areas for economic, social and environmental sustainability in constructions.

In keeping with tradition, the exhibition will be animated by thematic activities in specific sectors and cardinal events such as the Technical Innovation Competition and the International Award, which recognises industry figures for their work to promote the development and success of building industry activity. Moreover, the 2014 edition will also dedicate special space to a series of initiatives intended to celebrate the prestigious anniversary of 50 years since the first edition of Samoter.



When and where

8th - 11th May 2014
Thursday to Saturday, 9:30am - 6pm
Sunday, 9:30am - 4pm

Verona is at the crossroads of the Venice (115km) - Milan (160km) motorway and the Brennero (220 km) - Bologna (140km) motorway and can be easily reached by road or rail. The Exhibition Centre is about 3 km out of the city centre, and a few minutes drive from the Verona sud exit (Venice-Milan motorway).

A dual carriageway connects the Exhibition Centre to the local Airport (Valerio Catullo), a taxi from the airport is approximately EUR 16.

The 2014 edition of *Samoter* is this year hosted by Verona. The show attracts a broad caucus from the construction industry

International Innovation Competition

This international showcase for technical and technological developments premiered during the event intends to reward the results of innovative investments by offering interested entrepreneurs and technologists the chance to extend their knowledge of the technical-construction and functional evolution affecting various aspects of site activities.

The award is made by taking into account innovations and/or improvements concerning the optimization of human and economic resources, environmental and energy sustainability, ergonomics, safety in use and all other aspects that ensure added value for products.

The Competition is open to machinery, equipment, plant and prototypes characterised by new design and/or practical innovations in use, as well as fundamental improvements to existing machines.



Samoter Awards for projects and significant works

The Samoter International Award was launched in 1973. The award is made to people distinguished through their contributions to the development and success of building and site activities on a national and international scale in terms of technological innovation and scientific research. Five categories are involved: Foreign Countries, Designers, Machinery Builders, Italian Companies and Foreign Companies.

The 50th anniversary edition of Samoter will welcome special awards for the countries winning this prestigious recognition since 1973. These are: Algeria, Saudi Arabia, Australia, Brazil, China, Dubai, Egypt, Ethiopia, India, Iran, Morocco, Nigeria, Pakistan, Panama, Portugal, Russia, Spain and Turkey.

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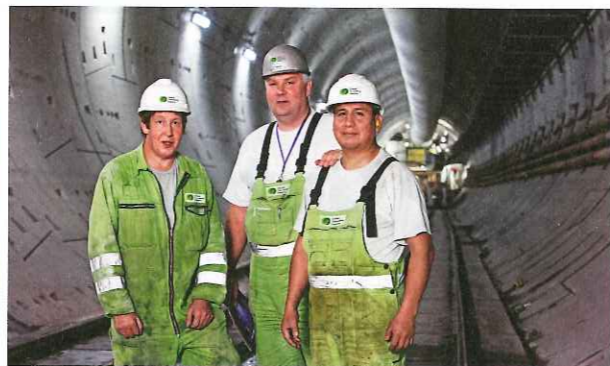
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What's on

2014

Samoter
8-11 May 2014
Verona, Italy
This trade show dedicated to earth moving, site and construction machinery is held every three years. In 2011, the exhibition attracted 98,000 visitors and more than 900 exhibitors (of which almost 30 per cent were international).
www.samoter.it

World Tunnel Congress 2014
9-15 May 2014
Iguassu Falls, Brazil
Organised by the Brazilian Tunnelling Committee of the ABMS (the Brazilian Association of Soil Mechanics and Geotechnical Engineering), as well as the International Tunnelling Association, and focusing on "Tunnels for Better Living", WTC 2014 will discuss and illustrate the importance of tunnels.
www.wtc2014.com.br

15th Australasian Tunnelling Conference
17-19 September 2014
Sydney, Australia
The 15th Australasian Tunnelling Society (ATS) Triennial Conference will be held in Australia's largest city, Sydney. This conference is the industry's opportunity to share in the knowledge, share project and application experiences and provide you the opportunity to hear what others have to say. Including case studies showing applications of new technologies in tunnelling.
www.atstunnellingconference2014.com

Intertunnel 2014
14-16 May 2014
Moscow, Russia
Intertunnel exhibitors come from all sectors of the tunnelling supply and services industries to present systems needed to construct, equip and operate tunnels and underground spaces. Topics covered will include: Tunnel construction equipment, materials and plant, microtunnelling and trenchless, fire protection, communications, security, pollution control and ventilation equipment, electrical and lighting.
www.intertunnelrussia.com

North American Tunneling Conference
22-25 June 2014
Los Angeles, California
The US Underground Construction Association (UCA)'s biennial tunnelling conference takes place in Los Angeles, California in 2014.
www.smenet.org

Tunnel Expo Turkey
28-31 August 2014
Istanbul, Turkey
The number of newly-excavated tunnels in Turkey is among the highest in the world, and in Istanbul, a great number of infrastructure tunnels are planned to be excavated soon, worth more than USD 10bn. Demos Faurecilik, in association with the Turkish Tunneling Society, is organising the third short course on tunnelling in Istanbul, along with a tunnel technology fair.
www.demosfuar.com.tr

15th Australasian Tunnelling Conference
17-19 September 2014
Sydney, Australia
The Australasian Tunnelling Society's triennial conference, and registration is scheduled to open online this month.
www.atstunnellingconference2014.com

InnoTrans
23-26 September 2014
Berlin, Germany
An international platform for buyers and sellers of passenger and freight transport technology, InnoTrans focuses on railway technology. The Tunnel Construction segment will be accompanied by International Tunnel Forum featuring a series of international discussions
www.innotrans.de

TAC 2014 Annual Conference
26-28 October 2014
Vancouver, British Columbia
The Tunnelling Association of Canada's Vancouver TAC 2014: Tunnelling in a Resource Driven World will include plenary presentations, technical sessions, and a trade exhibition all designed to highlight advancements in tunnelling research and practice from around the globe. This event will include TAC's Annual General Meeting and Awards at the Sheraton Wall Centre Hotel.
www.tac2014.ca

2015

Shotcrete conference and exhibition
29-30 January 2015
Tyrol, Austria
Wolfgang Kusterle and his team welcome you to the Conference and Exhibition Shotcrete 2015 at the Alpbach Conference Centre. Knowledge and experience do not help, if they remain hidden. This platform has gathered shotcrete specialists for 25 years, in a surrounding field where the exchange easily takes place.
www.spritzbeton-tagung.com

World Tunnel Congress 2015
22-28 May 2015
Dubrovnik, Croatia
The jewel of the tunnelling calendar heads to the Dalmatian Coast for the technical event of 2015 as WTC returns to Europe. Details to be confirmed.
www.wtc15.com

RETC
7-10 June 2015
New Orleans, Louisiana
The Underground Construction Association's biennial conference.
www.smenet.org

British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Events are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month.

C310 Thames Tunnel
15 May 2014
Riku Tauriainen, project director, Andreas Raedle, technical and risk manager, Andy Ingram, construction manager from the Hochtief Murphy JV discuss the geotechnical and tunnelling related specifics in urban tunnelling and river crossing with low overburden.

What could possibly go wrong with a site investigation in chalk?
16 October 2014
Roy Mortimer of Brighton University reviews case histories and the importance of site investigations and the analysis of the results. Including case studies demonstrating good and bad practice.

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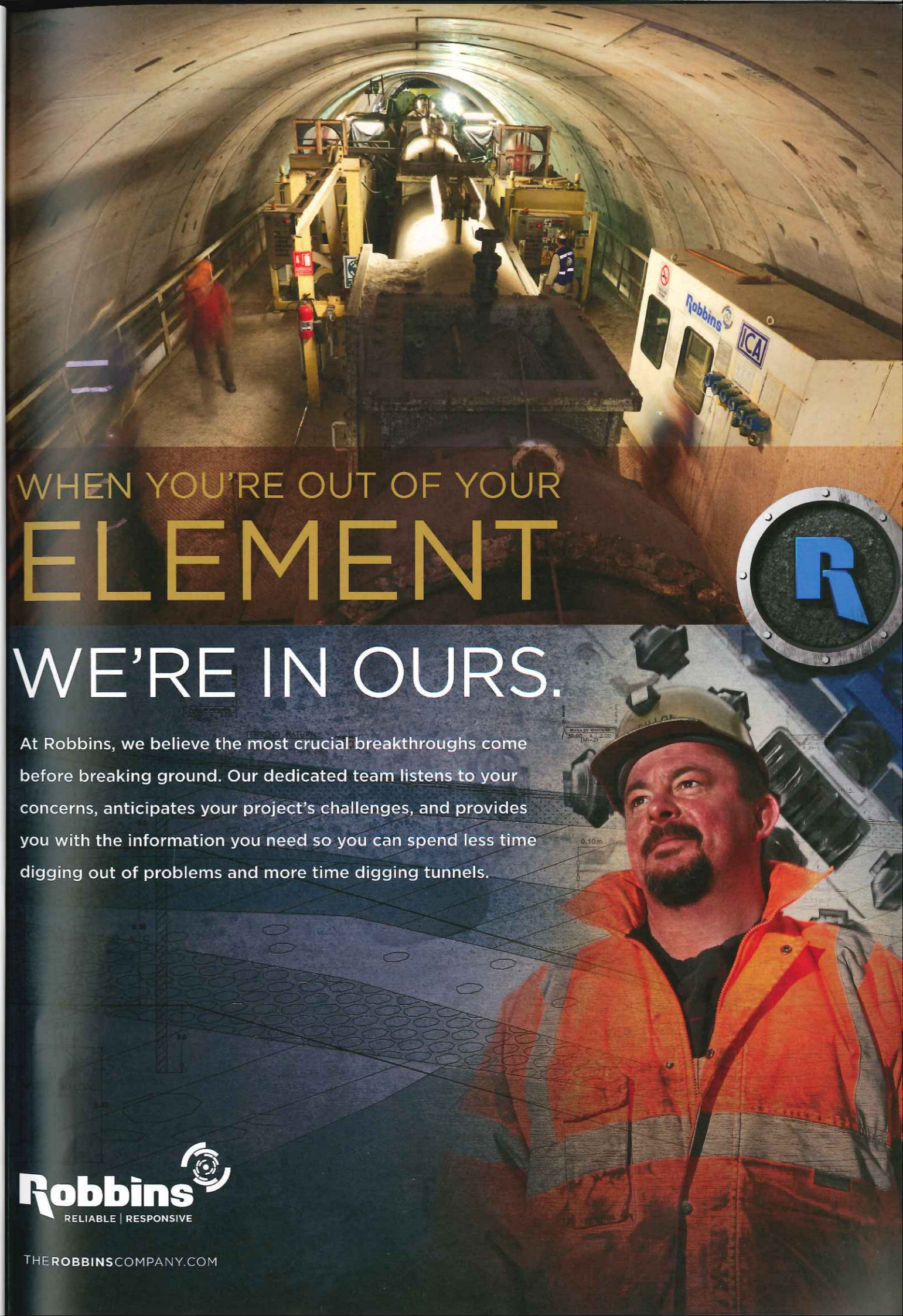
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