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UNDERGROUND ●

**12 UNITS OF
SPM 500 WETKRET
CONCRETE SPRAYING SYSTEMS
TO PROVIDE ROCK-SUPPORT
IN THE SUHUA HIGHWAY
UPGRADE PROJECT IN TAIWAN**

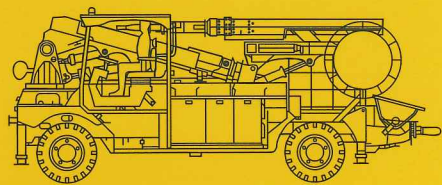
"We are proud that our equipment meets the requirements of Kung Sing Engineering Group for concrete spraying in tunnel construction" said Max Eckstein, International Sales Manager of the Putzmeister Underground Division. According to the agreement, Putzmeister will provide Kung Sing Engineering Group with 12 units of SPM 500 WETKRET concrete spraying systems to be used in the construction of the Kuan-yin (B2 section) and Ku-feng tunnel (B3 section) in the Suhua Highway upgrade project. The two tunnels have an overall length of approximately 13 km, with the construction works being 7,94 km and 4,66 km each.

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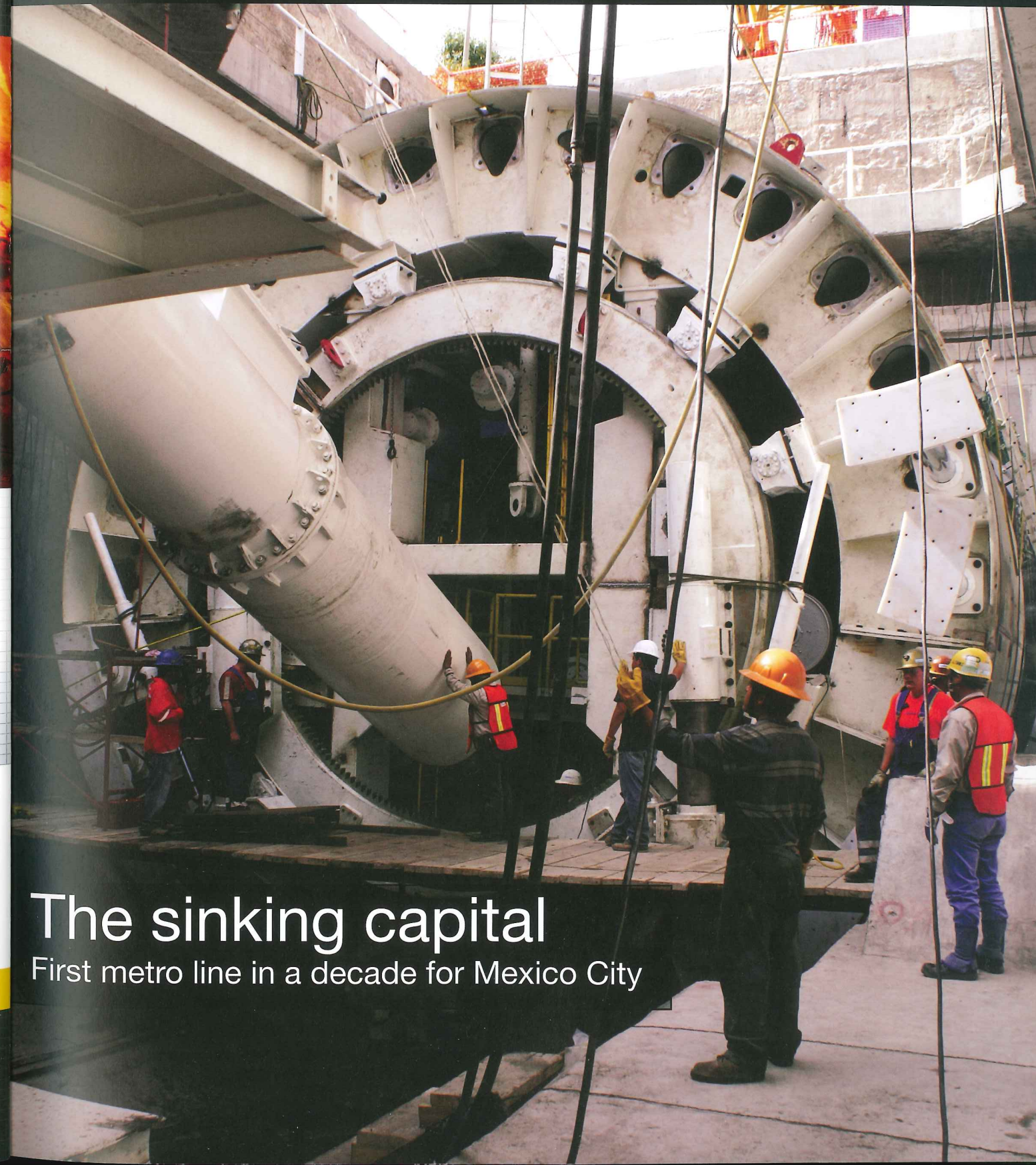
Latin America

The sleeping giant stirs, T&T looks at the drivers for hydropower and metros

Tunnel lighting

Concerns of cost, diffusion and bandwagons

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The sinking capital First metro line in a decade for Mexico City



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Technology Construction companies all over the world have already excavated more than 750 kilometers of tunnel for new metro networks using Herrenknecht tunnel boring machines.

Application In Asia Pacific alone, Herrenknecht has received orders for tunnel boring technology in more than 300 projects. Many of these take place in the booming metropolises of China, India and Singapore, where great efforts are being made to expand metro networks in order to meet the huge demands for efficient means of transport. In the USA, Herrenknecht delivered projects 5 machines used for tunnelling in both hard rock and soft ground to extend the New York City subway. And, on the opposite side of the country, jobsite crews in Seattle celebrated the tunnelling breakthrough of two Herrenknecht Earth Pressure Balance Shields in March and April 2012, which had been working on the University Link Light Rail project. High performances were also achieved closer to home on the Wehrhahn Linie project in Düsseldorf, Germany. There our customers achieved weekly performances of up to 75 meters while tunnelling in some sections only four meters below the busy city center and through particularly abrasive soil.

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Chance on Thailand

Many, including the World Bank, consider Thailand to be one of the great development success stories, with sustained strong growth and impressive poverty reduction. The Thai economy was one of the world's fastest growing in the decade ending 1995, with an average rate of eight to nine per cent a year, according to the World Bank. Following the Asian Crisis of 1997-98 the country managed a growth rate of around five per cent a year.

The International Tunnelling Association has taken heed of this success and is hosting World Tunnel Congress 2012 in Bangkok this month (see show preview, page 51). The show is expected to attract the usual high levels of exhibitors and attendees as well as publishing an extensive list of technical papers.

The tunnelling market in Thailand has come in fits and starts. The floods that struck Bangkok in autumn 2011 have spurred investment in huge drainage tunnels for the city. Prior to the floods the Bangkok Metropolitan Administration announced a USD 541M Giant Tunnels programme to prevent large scale floods. Just months before the flood construction completed on the first tunnel, 5km long and 5m in diameter.

The floods caused large-scale loss to businesses and adversely affected investor confidence. This gave further impetus to the project and work was started on a 6.5km long, 5m-diameter tunnel and a 13.5km long, 6m-diameter tunnel, worth USD 68M and USD 153M respectively. Both tunnels are due to complete in 2015, according to the *Construction Intelligence Centre (CIC)*, which is also from *T&T* publisher World Market Intelligence (www.construction-intelligence.com).

In line with Thailand's somewhat unpredictable tunnelling sector, Phuket's Patong road tunnel remains on hold. The 3.25km twin bore road tunnel is to cross the hills that separate Patong from the rest of the Kathu region near Phuket. The USD 201M project was put on hold due to costs, but the recent addition of tolling to the plans means the project could be completed in five years.

There are strong opportunities in Thailand's construction market for the coming years. The construction industry was valued at USD 12.8bn in 2011. According to the *CIC*, the infrastructure construction market comprised 27.8 per cent of the construction industry value, and grew at a compound annual growth rate (CAGR) of 0.61 per cent during 2007-2011. Thailand has a highly export-dependent economy, and therefore the government is developing infrastructure in line with industrial growth. Many of Thailand's leading sectors, such as tourism, require infrastructural support and to this end the government is allocating funds for modernisation.

During 2009-2011, the government announced that the country is to allocate THB 2.1tn (USD 70bn) for infrastructure expenditure and THB 349.6bn (USD 11.4bn) for water management infrastructure. In mid-2009, the Electricity Generating Authority of Thailand (EGAT) announced plans to spend THB 20.6bn (USD 644M) on renewable energy projects, mainly hydropower.

The Thai government is planning to launch a series of infrastructure funds, which will drive construction activity over the next five years. One such project is the THB 1.5tn (USD 50bn), 615km Thailand-Laos-China High-Speed Railway Line project.

The State Railway of Thailand (SRT) is to implement substantial upgrades to its existing rail infrastructure with a total investment of THB 176.8bn (USD 5.8bn) for 2010-2014. As a consequence of such developments the market is expected to record a CAGR of 0.22 per cent during 2010-2014.

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Power up the future

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On the cover:
Boring the first new line

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- ✔ Extremely abrasive ground and up to 7.3 bar pressure.
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International Tunnelling Awards 2011
Tunnelling Contractor of the Year – WINNER: Jay Dee Coluccio Taisei & Jay Dee Coluccio JVs

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HS2 awards preliminary design and environmental contracts

GREAT BRITAIN

Client High Speed Two (HS2) announced last month that it has awarded four contracts for civil and structural design services. The companies will prepare preliminary designs that will inform the hybrid bill documents to be submitted to the UK Parliament by the end of 2013. The contracts were part of 'Lot One: Professional Services Framework' and in addition, HS2 awarded its remaining four contracts under 'Lot Three Environmental Services'.

Of the design contracts, Mott MacDonald was awarded the GBP 13.2M (USD 20.97M) 'London Metropolitan Area' contract. It covered some 25km of new HSR line from Euston running through northwest London, with work on the link to HS1 and a 14-platform interchange at Old Oak Common. London Mayor Boris Johnson has pledged to argue for increased

tunnelling in the London area to avoid surface disruption.

Atkins won the GBP 13.3M (USD 21.13M) 'Country South' contract for 91km of line through Buckinghamshire, Northamptonshire and Oxfordshire. The contract covers tunnelling through the Chilterns.

Capita Symonds Ineco's GBP 11.1M (USD 17.6M) 'Country North' contract covers 78km through Warwickshire and Staffordshire, with a connection to the West Coast Main Line.

Arup has a GBP 11.4M (USD 18.1M) 'West Midland Metropolitan Area' design contract covering some 22km of the route. It includes the Curzon Street station complex, Birmingham interchange station, Washwood Heath rolling stock maintenance depot and a people mover from the interchange station to the airport.

Of the EIS work, two contracts were won by the ERM Temple Group Mott MacDonald

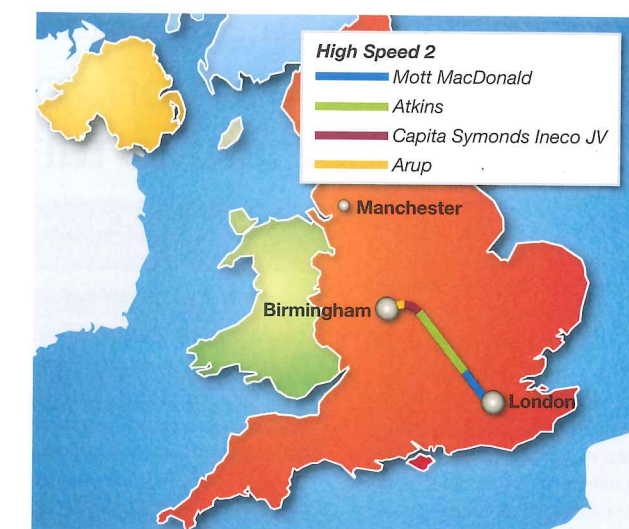
consortium. The contracts cover the London area and the 'rural south' section of Buckingham, Hertfordshire, Oxfordshire and Northamptonshire. The contracts were worth around GBP 7M (USD 11.3M) each.

Atkins was given the GBP 5.5M

(USD 8.9M) responsibility for assessing the 'rural north' section of the route, covering the counties of Warwickshire and Staffordshire.

Arup and URS will assess the West Midlands metropolitan area focusing on Birmingham and Solihull for GBP 5M (USD 8M).

Below: HS2 preliminary design sections by contracted company



EIS submission moves NWRL project forward

AUSTRALIA

The first of two environmental impact statements (EIS) for the 23km North West Rail Link in Sydney, Australia was released last month. The announcement followed a statement on 12 March that the New South Wales Government would secure an additional transport corridor for future expansion.

New South Wales Premier and minister for Western Sydney Barry O'Farrell said, "The release of this EIS is further evidence the NSW Government is getting on with the job of delivering the North West Rail Link. This is the most important transport project in the country, and we are proceeding full steam ahead

with its delivery."

The EIS was released for public exhibition for 48 days until 21 May. Eight public sessions will form part of the exhibition including sessions on specific topics such as noise and vibration, construction traffic and construction methods.

Minister for Transport Galdys Berejiklian said, "We are building tunnels almost six times longer than the Sydney Harbour Tunnel. The economic benefits of the North West Rail Link are immense – the new line will support more than 16,200 jobs during construction and inject about AUD 25bn (AUD 24bn) into the NSW economy."

Some 17 construction sites will be set up along the alignment. Major tunnelling work will begin in

2014 (see feature, T&T March 2012, page 34). State government estimates valued the project at over USD 8bn. Design services are being provided by Aecom, Parsons

Brinckerhoff, Cox Architects and Grimshaw Architects.

The EIS can be read at northwextrail.com.au. The second will be released later in 2012.

Below: Concept image of a North West Rail Link station entrance



USDOT USD 422M loan approved for 2.1bn Midtown Tunnel project

USA

The US Department of Transportation (USDOT) last month approved a USD 422M loan in credit assistance for the Midtown Tunnel project crossing the main channel of the Elizabeth River in Virginia to link the cities of Norfolk and Portsmouth.

The Midtown Tunnel project has

been valued at an estimated USD 2.1bn and will construct a second Midtown Tunnel parallel to the existing one. Rehabilitation of the existing tunnel and two downtown tunnels will also be carried out.

The existing Midtown tunnel was opened in 1962 and during its first year of operation carried some 8,400 vehicles per day but now cope with 38,000 a day. The

tunnel is approximately 1km long.

Tolls were removed from the Midtown and Downtown tunnels in the mid 1980s after the original bond debt had been paid.

The loan is part of the USDOT's 'Infrastructure Finance Innovation Act'. The aim is to reduce future tolls by lowering project finance costs with flexible lending terms.

The Virginia Department of Transportation (VDOT) entered into a public-private partnership (PPP) with Elizabeth River Crossings Opco (ERC), which will be responsible for the financing, design, construction, tolling and ongoing operations and maintenance of the project for the 58-year concession. VDOT will be sole owner of the project.

Split industry opinions on advance rate bonuses paid to tunnel workers

GLOBAL

A T&T opinion poll taken in April found that 57.1 per cent of readers thought that tunnel miners should be given bonuses for increasing advance rates. One anonymous comment said, "Working on a fixed wage regardless of progress is a disincentive, or rather an incentive to go slowly and make the project last."

Other comments voiced concern about possible compromises in quality if advance rate is the sole priority. One argued that advancing beyond what is expected or planned for is unwise. Another said that workers in the



Above: The anonymous poll showed a split in the community

tunnel do not care about health, safety or design considerations.

Dickie Dexter, tunnelling construction director for UK-based subcontractor Joseph Gallagher argued, "This is an old problem, although in modern tunnelling it is generally the case that bonuses are also linked to quality and safety. And losing a bonus

collectively means continuous and quality productivity from one shift and the next.

"The industry was built over years on piece work, and to get rid of it would be a massive change in practice. It is an incentive that benefits management as well as workers, considering the large overheads in construction."

Bad Cannstatt awarded to Alpine-Hochtief-W&F JV

GREAT BRITAIN

The EUR 290M (USD 386.66M) Bad Cannstatt rail tunnel contract was awarded to the Alpine-Hochtief-Wayss & Freytag partnership. Client Deutsche Bahn gave the JV until 2018 to complete the project. Preparatory work will begin in 2012 with excavation beginning in 2013.

The Bad Cannstatt tunnel in southern Germany will connect

Stuttgart Central Station to the yet to be built Neckar Bridge as part of the Stuttgart 21 section of the Stuttgart to Ulm rail link.

Approximately half of the 117km link will run through some 16 tunnels. The contract covers 5.5km of single track mainline tunnel with 600m double-track and 400m of single track S-Bahn (metro) tunnel with 600m of double track. Excavation will be by milling machines and drill and blast as

geology dictates. Investigations revealed drained and undrained gypsum of the Keuper unit.

A double lining of sprayed concrete and plastic seal will be used in the tunnel.

The line forms part of the 1,500km Magistrale backbone of the Trans European Rail Network. Alpine's tunnelling managing director Josef Arnold said that it was the sixth tunnel the company had won from Deutsche Bahn.

News in brief

▼ **Crossrail awards Victoria Dock portal contract to Vinci** Contract 340 Victoria Dock Portal was awarded to Vinci Construction UK. Andy Mitchell, London's Crossrail programme director said, "Crossrail has awarded the last portal contract. The Royal Oak Portal was completed last year. Construction of the portals at Pudding Mill Lane and Plumstead are underway. Construction of the North Woolwich portal will begin in May 2012 and Victoria Dock in autumn 2012."

▼ **Fast-track tunnel plan to unlock Kargil, India** People's Democratic Party (PDP) president Mehbooba Mufti last month spoke in favour of fast-tracking a tunnel project. The alignment would run across Zoji La, a mountain pass in Jammu and Kashmir, India.

▼ **Keller awarded pits on first TBM road tunnel in Poland** Keller has been awarded a GBP 30M contract to construct access ramps and TBM launch and reception pits for a new road tunnel under Dead Vistula River near Gdansk, Poland. The twin-bore tunnel will be 1.1km long and 12m in diameter.

LU train hits seepage tunnel bulge

GREAT BRITAIN

One or more London Underground (LU) trains hit an obstruction on the Bakerloo Line as T&T went to press. A source close to LU told T&T, "An area of water ingress was patched up with quick-drying cement. This bulged out suddenly and is what three or four trains hit. The area [located between Elephant & Castle and Piccadilly Circus] was reinforced with steel supports some 10-15 years ago."

The incident occurred as the rapid response unit of Transport for London (TFL)'s asset management subsidiary Tube Lines was on strike. LU operations director Nigel Holness said, "There is no tunnel collapse in the Bakerloo line, nor is there any flooding or injuries. It is irresponsible to suggest otherwise.

"Our engineers are on site [...] and have advised there is no flooding or risk of flooding or any collapse of the tunnel. The problems this morning are not in any way connected with the

industrial action taken by some maintenance [staff] on the Jubilee, Northern and Piccadilly lines."

An employee bulletin later issued by LU said, "A 100mm piece of metal plate forming part of a non-structural inner lining ring was pushed slightly out and made contact with a passing train. Early indications are that the movement was caused by works to prevent water seepage."

Right: The bulge pushed a metal plate



Restart of Sao Paulo Metro Line 4

BRAZIL

Construction on the second phase of the Sao Paulo Line Four (Yellow) officially started last month. The project was launched by Sao Paulo governor Geraldo Aickman; Secretary of State for Metropolitan Transportation (STM) Juarandir Fernandes; and Sao Paulo Metro president Sergio Avelleda.

This phase includes a 1.5km tunnel drive for station access at Vila Sonia. Contracts for operating systems have yet to be put out to tender. The whole cost of the Line

Four (Yellow) project will be USD 5.6bn according to the metro company. It will take some USD 1.8bn to complete phase two.

The second phase includes five stations and is due for completion in 2014. A third phase is planned to extend the line from Vila Sonia Taboao station to the city of Serra over approximately 4.8km.

Phase One was fully opened, including late stations, in March 2011. The project is financed by the World Bank. Project management on both phases is by Finnish contractor Poyry, while local practice Companhia do

Metro will continue to monitor the ongoing operation.

Other current metro construction projects include the extensions of Line Five (Purple) and Line Two (Green). Work will soon begin on Line 17 (Gold) to Congonhas Airport, the contract having been signed.

The STM investment plan for 2011-2014 amounts to USD 26.2bn. By 2014 the Sao Paulo Metro is expected to exceed 100km in length, much of which is underground, in addition to the 300km length of CPTM Metroferroviaria lines.

News in brief

▼ **Lee Tunnel wins awards** The UK Institution of Civil Engineers awarded the Lee Tunnel in London its Greatest Contribution to London award and its Infrastructure Award. Standards have had to be high on the project to avoid pollution of a nearby drinking water aquifer. The judges said, "Sewers are unseen and often overlooked. Not only was the ambition of this project impressive but this relies on innovation which in turn relies on a real understanding of engineering skills and judgement."

U220 breakthroughs

USA

Breakthrough was reached on the first bore of the U220 University Link Light Rail in Washington, D.C., US. The 6.4m Herrenknecht machine completed the 3.2km drive on 21 March with a 3mm inaccuracy. The second breakthrough on the USD 2bn followed shortly after on 5 April. It was another Herrenknecht machine. A Hitachi Zosen machine was still approximately three quarters of the way through its 1.85km drive between Capitol Hill Station and the Pine Street

Stub Tunnel.

Soft ground along the alignment comprised glacial soils. Pressurised face TBMs were used and lining was one-pass precast concrete rings. The contractor was a JV of Traylor Brothers and Frontier Kemper. Jacobs Associates provided design project management and geotechnical engineering.

The TBMs that broke through were named Togo and Balto after sled dogs that helped transport medicine during a disease outbreak 90 years ago. The client was Sound Transit.

Tunnel as evidence in foiled Sicilian jewel heist

ITALY

A foiled jewellery heist in the Sicilian town of Acireale involved construction of a 1km-long tunnel in a month. The four-strong tunnel gang were spotted emerging from a manhole several metres from their target jewellery shop, where police say they were waiting for darkness to break through. Shovels and hand picks were used for excavation, with metal struts and wooden planks for support. Two-way radios

provided logistic communications and a small generator was used to power the lights, as well as torches attached to hard hats.

Part of the alignment ran alongside a sewer. All equipment was taken as evidence.

The historic centre of Acireale is known for its jewellers.

In Italy tunnels are occasionally used by mafia bosses for escape routes and hiding places. In 2009 police apprehended a gang leader with a 200m escape tunnel that led to a shaft that emerged into a field.

Terratec EPBM first in decade for Bangkok Metro

THAILAND

A Terratec EPBM was accepted by the Bangkok Metro Blue Line extension project on 27 March. Representatives of client Mass Rapid Transit Authority of Thailand (MRTA) and contractor Italian-Thai Development attended the ceremony in Guangzhou, China.

It will be the first TBM used on the Bangkok Metro project for 10 years. A Terratec spokesman said, "We are not sure of the details on this gap. An ambitious spending plan is only just being realised and we hope to see metro work in Bangkok expanding in the coming years."

The EPBM is a 6.44m machine that has been designed with a

cone cutterhead adapted for cutting through concrete piles along the alignment. The manufacturer listed other benefits of the cone as stable discharging and excavation. The machine was built with 675kW power, torque of 6,480kNm and a total thrust from 16 shield jacks of 40,000kN.

The Terratec spokesman added, "Challenges faced by the contractor include the stacking of the two tunnels in a narrow area in Bangkok's China Town. This has never been done in Thailand, though it is not so strange elsewhere, especially in Japan."

The contractor will also excavate on a 200m-radius curve for the 5.1km drive through clay and sand. Twelve articulation



Above: The Terratec EPBM was accepted at the end of March

jacks can angle the shield to by 1.5 degrees for a design curve of 160m-radius.

After the ceremony the

machine was shipped to the project site in Bangkok, Thailand with a view to begin excavation by the end of June.

Tunnel plug passes stress test

USA

The US Department of Homeland Security's Science and Technology Directorate tested an inflatable tunnel plug to contain flooding or harmful gases. The January test was undertaken in a dummy steel tunnel to see if the plug could hold back 35,000 gallons (159,113.2 litres) of pressurised

liquids and gases.

The five by 10m cylinder was made out of a strong but flexible material comprising three layers: a thick webbing made of Vectran, a liquid crystal polymer; a second, non-webbed layer of Vectran and a third layer of polyurethane. Single-layer plugs failed early, scale model pressure tests.

Compactly positioned in tunnel sections to act as an airbag

against floods, it can be rapidly inflated and then filled with water to make it sturdier. A design diameter greater than the tunnel id ensures a tight seal and envelopes irregularities in the lining, though too much material could create wrinkles that high-pressure water can traverse.

Further tests in 2012 will be undertaken with the future aim of marketing the device.

Mott wins intake design

INDIA

Infrastructure engineering organisation MARG of India has awarded Mott MacDonald a design contract for the sea-water intake, outfall and circulation cooling system for a 2x250MW lignite-fuelled thermal power plant at Padva in Bhavnagar, Gujarat, India.

MARG has until July 2013 to complete the work. The owner, Bhavnagar Energy is developing the plant to meet increasing power demand from the large industrial facilities in the district.

Mott MacDonald will undertake detailed engineering of the system including intake and offshore and onshore pipelines.

Project manager Ramesh Kumar said wave modelling and sedimentation studies would be crucial as the Gulf of Khambhat is one of the roughest seas in the world. Such studies will allow savings on armour stone units.

UK Health and Safety Executive cost recovery scheme delayed

GREAT BRITAIN

The Health and Safety Executive (HSE) did not implement its new cost recovery scheme at the start of April as planned. October was announced as the next likely target.

HSE programme director Gordon MacDonald said, "The Government has agreed that those

who break the law should pay their fair share of the costs to put things right - and not the public purse. It intends to proceed with the FFI [Fee For Intervention] scheme as recommended to ministers by HSE's Board in December 2011.

"Discussions are still taking place on the technical details of the scheme, which we expect to conclude soon. Therefore, FFI will

not be introduced in April but at the next available opportunity, which is likely to be October."

The FFI scheme will see costs for HSE operations covered by companies that break health and safety laws.

Compliant companies will not be charged. Guidance will be published on the HSE website.

A HSE spokesman said the organisation would "take advantage of the extra time to work with businesses to improve understanding of the scheme."

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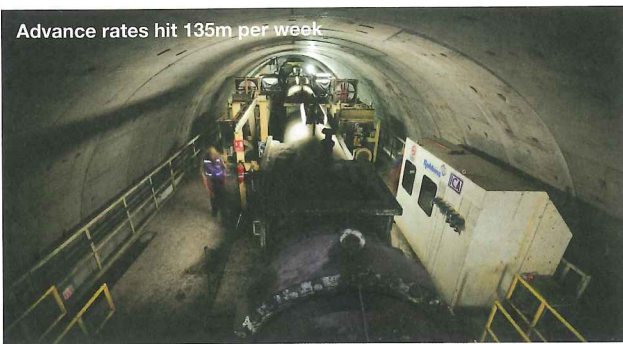
*Learn more about iSURE at www.understandingunderground.sandvik.com

www.construction.sandvik.com

SANDVIK

Mexico City Metro Line 12 completes excavation

Advance rates hit 135m per week



MEXICO

Excavation finished last month on Line 12 of the Mexico City Metro. A 10.2m Robbins EPBM completed the 7.7km drive. The contractor was a JV of ICA, Carso and Alstom.

Ground was variable and included watery clays, cobbles and large boulders. The machine was launched in February 2010 and emerged on 1 March after breaking through seven cut and cover station sites that ranged from 150 to 190m in length.

Advance rates hit 135m per week and averaged 400m per month. This was helped by active

articulation that permitted curves of down to a 250m radius. A two-stage screw conveyor with an initial ribbon-type screw allowed for boulders up to 800mm.

Real-time settlement monitoring was necessarily rigorous. At one stage the machine was within metres of a 16th century church. A two-liquid back-filling system with rapidly hardening cement reduced settlement, which stayed within the limits of 20 to 50mm.

The new 25.4km line, the longest of the metro system, will be the first for 10 years in the 20 million-strong Mexico City and will carry around 350,000 passengers daily (see feature, page 30).

Australian National Tunnelling Code of Practice announced amidst concern

AUSTRALIA

The Australasian Tunnelling Society (ATS) has criticised areas of the proposed National Tunnelling Code of Practice. At a workshop in Brisbane last month that presented a new Queensland Code of Practice induction, it was announced that a harmonisation programme will see the changes adopted in other states.

An ATS spokesman said, "In the opinion of the ATS, there are a number of inclusions in the revised code which are potentially onerous and/or ambiguous.

"ATS intends to prepare a coordinated response on behalf of

its members to the respective safety authorities in the other states. In the near future ATS will be seeking further input and involvement from our members on this issue."

The spokesman added that the clause on mandatory escape routes on page 24 of the full document was an example of an area of concern to the ATS.

The full document can be viewed here: www.deir.qld.gov.au/workplace/resources/pdfs/tunnelling-cop-2007-2010.pdf

A list of changes can be viewed at: www.deir.qld.gov.au/workplace/resources/pdfs/tunnelling-cop-errata.pdf

Crossrail fit-out shortlist

GREAT BRITAIN

Crossrail announced the shortlist for the GBP 400M (USD 641M) major tunnel fit-out services contract, C610.

The bidding parties were: Alstom Transport-TSO-Costain JV; Balfour Beatty Rail; BAM Nuttall-Ferrovial Agroman-Kier Construction JV; Laing O'Rourke-Volker Rail JV and a JV of Rhomberg Bahntechnik-Alpine-FCC Construcción.

A Crossrail spokesman said, "Work will include the installation of over 40km of track, overhead electric conductor rails, as well as ventilation and drainage systems.

The tunnels will also require over 50 ventilation fans, some 40km of walkways, 60 drainage pumps and 30km of fire mains as well as lighting throughout the entire length."

The tunnel fit-out works contract will be one of the largest contracts to be let by Crossrail.

TBM moves for London Power tunnel project

GREAT BRITAIN

Abnormal Load Services (ALS) has transported a 4.72m-diameter Herrenknecht TBM from the manufacturer's Schwanau headquarters to National Grid's difficult-to-access construction site in the Haringey area of north London, UK.

Costain will use the TBM on the first of two drives for the National Grid's London Power Tunnels Project (see feature, page 76).

ALS delivered the TBM in five oversize 'breakbulk' components and 17 standard container loads. Loads were transported by road to a waterway where they were lifted onto a barge to be carried to the Zeebrugge ferry port in Belgium.

Special arrangements had to be made at Zeebrugge in transferring

News in brief

▼ Soderstrom's new pumps

The Soderstrom rail tunnel project in Stockholm, Sweden has employed Tsurumi pumps to end delays. Six LH23.0W pumps were ordered. A 300m section of the tunnel will comprise submerged, 100m-long prefabricated tunnel sections. These are supported on four grouped piles. The pumps will be used during the installation of these sections. Cut and cover channels were dug at each side of the bay to link the submerged sections with the land tunnel. The 20m-deep channels are the deepest in northern Europe and are held in place by 1.5m-diameter piles.

▼ Ferrovial wins Galicia HSR

Ferrovial Agroman was awarded a USD 143.5M contract to build a section of the Madrid-Galicia HSR line. Work includes a 6.4km gallery connecting to the existing Pardonele tunnel.

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Leighton Holdings accepts infringement notices...

AUSTRALIA

Leighton Holdings said that without admitting liability, it accepts the notices issued by the Australian Securities and Investments Commission related to the earnings downgrade issued in April 2011. It will pay AUD 300,000 (USD 315,450).

Leighton Holdings chairman Stephen Johns said, "We take

our continuous disclosure obligations very seriously and have undertaken to ASIC to implement an independent review of our systems.

"We recognise that continuous disclosure is extremely important for the efficient operation of the market and will use the review as part of our program to improve the systems that support our business. We will commence the

review as soon as practical.

"The infringement notices allow Leighton to move on from the events surrounding the earnings downgrade last year. This enables the management team, led by [CEO] Hamish Tyrwhitt, to focus on the operations of the business.

"They are not an admission of liability nor a finding of any breach of law."

...and acknowledges project performance deterioration

AUSTRALIA

Leighton Holdings last month identified a "deterioration in the financial performance of [the Brisbane] Airport Link and the Victorian Desalination Project". It will result in a forecast profit reduction of AUD 254M (USD 263.6M) before tax reflected in the current financial year to 31 December 2012.

Leighton CEO Hamish Tyrwhitt expressed deep disappointment at the change from the December 2011 quarterly reviews. He added that the company had believed then that the Brisbane Airport Link and Victorian Desalination Project performances had both stabilised.

Tyrwhitt added, "Wet weather in

Brisbane, productivity below expectations at both sites combined with the complexity of the commissioning of the integrated systems at Airport Link have seen an unanticipated increase in forecast costs and denied us the level of performance that we were expecting or needed on those projects.

"The deterioration at Airport Link is, in part, due to the acceleration of the commissioning which started in February and it is now forecast to be more costly than anticipated. Forecast productivity on the site is not being achieved and consequently we are having to substantially increase the size of the workforce to deliver the project. Unseasonably wet

weather since the middle of February has also caused delays which impacted the completion of the construction of the tunnel portals and the access ramps, and delayed asphaltting of the road."

On the Victorian Desalination Project, Tyrwhitt said deterioration was due to some construction slippage and flooding of the intake and outtake tunnels.

Tyrwhitt said that despite these projects, the company has a 'solid' balance sheet and has work in hand of USD 45.9bn. He said, "We are targeting completion of APL by around the middle of the year and VDP by the end of the year which allows us to move forward and take advantage of opportunities [that emerge]."

Arup looks to Tanner for infrastructure leadership

AUSTRALIA

Bruce Tanner has been made leader of Arup's 650-strong Australasian infrastructure department. Formerly in charge of the Queensland team, he took over from the retiring Frank Vromans at the end on March.

Vromans said, "In his new role, Bruce will draw on his strong leadership ability and in-

depth knowledge and understanding of infrastructure's role in economic and social development. Bruce has made an enormous contribution to the industry over the years and I have every confidence that he will take infrastructure to the next level."

An Arup spokesman added, "Bruce has been with Arup for more than 20 years and in that

time has gained extensive experience in developing and driving large teams [across many disciplines] carrying out complex studies for major infrastructure projects.

"He has a strong technical background based on direct design experience in all aspects of infrastructure works including highways, rail, aviation and development."

News in brief

▼ **Normet wins Finnish 'internationalisation' award**
Finnish president Tarja Halonen awarded the country's 'Internationalisation' award to mining and tunnelling services and equipment supplier Normet. The award is given in recognition of an internationally successful Finnish company. Normet won the award in the 'growth company' category.

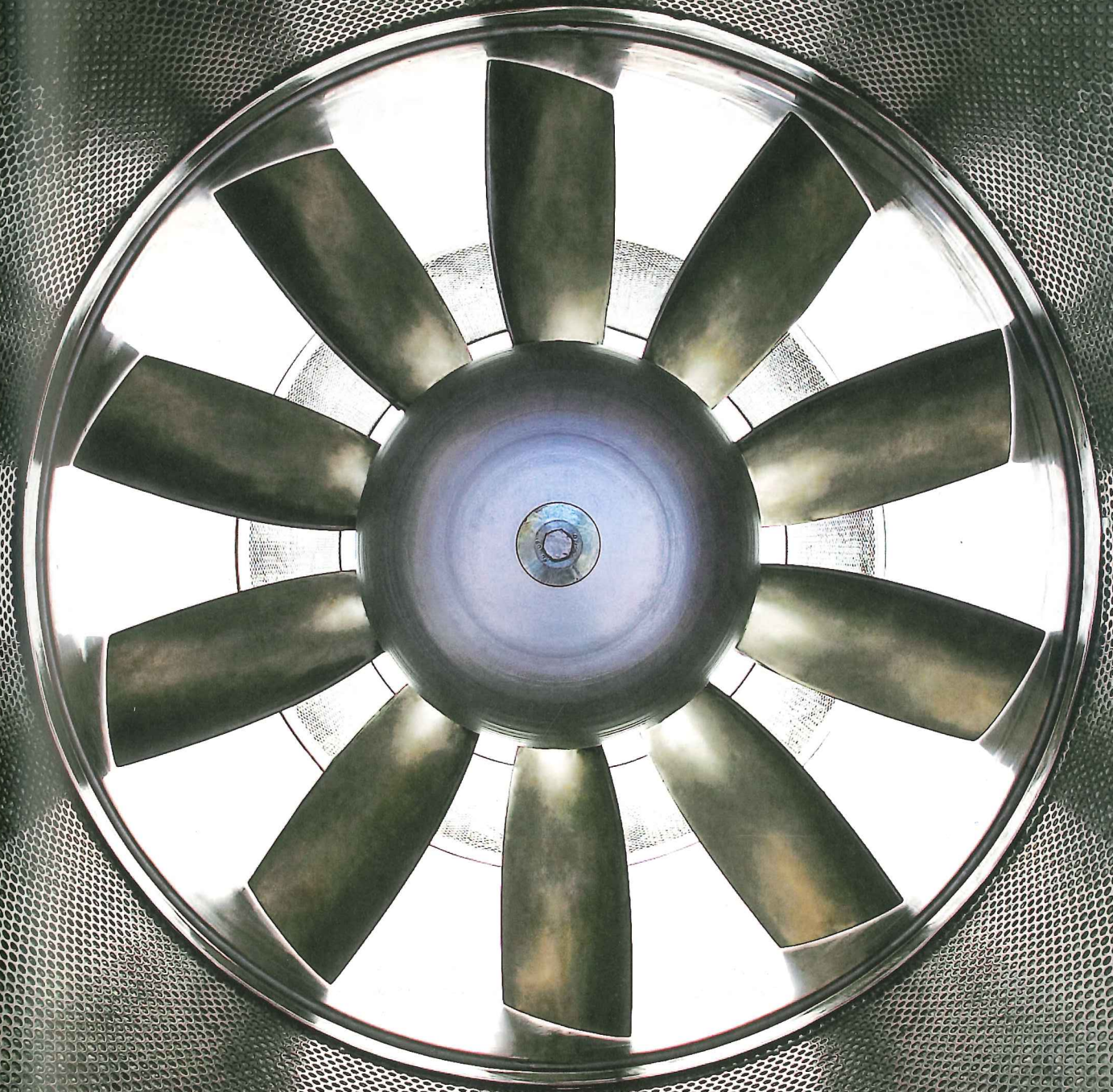
▼ **Itmsoil launches training courses on monitoring**
The courses are aimed at giving engineers an understanding of monitoring in civil engineering and clients an idea of the value of good practice. The courses will be organised by University College London and will be based on the contents of the new guide to instrumentation in geotechnics by Richard Bassett. Bassett will also be the technical consultant to the course. To book your place for September, visit www.mce-training.com

▼ **Atlas Copco opens new office in Mozambique**
Swedish manufacturer Atlas Copco has opened a new customer centre in Mozambique. The centre will cater to the surface mining, exploration, drilling and compressed air services. The company previously dealt with the country via its South Africa office.

▼ **DMRC director steps down**
Shri Kumar Keshav, director of project and planning for the Delhi Metro Rail Corporation (DMRC) resigned from his post on 18 April 2012 on personal grounds. The resignation was accepted the following day by the board of directors. Keshav joined DMRC in 2002.



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Keller director Jimenez steps down from board

GREAT BRITAIN

Pedro Lopez Jimenez will stand down from his position as non-executive director on the board of UK-based ground engineering giant Keller. The company had intended to re-elect him a director at the AGM.

Jimenez is also the chairman of Dragados, non-executive director of Hochtief and executive board member of construction group Actividades de Construccion y Servicios and the chairman of GTCEISU, a 49 per cent shareholder in Keller-Terra.

Roy Franklin, Keller chairman said, "Over the years, Pedro has

brought to the board exceptional knowledge and experience of our niche sector of the construction industry. Together with his international perspective and creative approach, this has enabled him to play a significant role in helping to develop the group.

"On behalf of myself and my colleagues on the board, I would like to take this opportunity to thank Pedro for the important contribution he has made to our business over these years and to wish him well in all his future plans."

Right: Jimenez steps down



Taylor Woodrow division boosts Vinci

GREAT BRITAIN

Vinci Construction UK announced turnover of GBP 1.11bn (USD 1.77bn) in 2011, up eight per cent on the previous year. The Taylor Woodrow civil engineering division's existing building activities were largely

credited with the growth.

Operating profits fell from GBP 28.4M (USD 45.3M) in 2010 to GBP 22.3M (USD 35.58M). According to Vinci, this was due to difficult market conditions. Net cash generated was GBP 3M (USD 4.79M) after PFI investments of GBP 15M (USD

23.9M). Dividends paid totalled GBP 5M (USD 7.98M) and cash balance increased from GBP 150M (USD 239.3M) last year to GBP 156M (USD 248.9M).

Chief executive of Vinci John Stanion said, "In the current difficult economic climate, these are encouraging results."

Bechtel boasts 18 per cent revenue jump

USA

Engineering giant Bechtel last month announced an 18 per cent increase in revenue year-on-year to USD 32.9bn for 2011, up from USD 27.9bn in 2010. The increase follows a two-year-long revenue shrink from a 2008 high of USD 31.4bn. The results were published in the firm's 2012 annual report.

Order book growth was large, climbing from USD 21.3bn in 2010 to USD 53bn in 2011. Again, the recessive trend from 2008 was evident, however the

order book 2008 high was only USD 35bn.

A Bechtel spokesman pointed to growth in its civil infrastructure division, and made special mention of Crossrail in the UK, Dulles Corridor in the US and the Rio de Janeiro metro in Brazil. "We are supporting the delivery of transport for London's new east-west rail link called Crossrail, Europe's largest current infrastructure project.

"We also continue to provide project management services for upgrades at the adjacent Crossrail & Reading project for

longtime customer Network Rail. At year's end, we replaced Reading Station's Cow Lane Bridge in just four days, a great achievement.

"Under another new contract, our Rail team is assisting Metro Rio with delivery of rolling stock for Rio de Janeiro's subway system, marking Bechtel's return to Brazil. And our Dulles Corridor Metrorail project team made substantial progress last year near Washington, D.C., extending the metro in Northern Virginia for the Metropolitan Washington Airports Authority."

News in brief

▼ **DSD invites tenders for Happy Valley storm storage**
The Hong Kong Drainage Services Department last month invited tenders to construct the Happy Valley Underground Stormwater Storage Scheme. Work will commence in July for completion in February 2018. Work will feature a 60,000cu.m storage tank. Tenders should be submitted by 18 May.

▼ **LU announces Bank Station prequalified bids**
London Underground last month announced the shortlist of companies that can enter the next procurement phase for the Bank Station capacity upgrade. The firms were: BFK JV (BAM Nuttall, Ferrovial and Kier), CVC JV (Costain, Vinci Grand Projets & Vinci Construction), Dragados and the MBA JV (Morgan Sindall, Balfour Beatty and Alpine).

▼ **Poyry releases January to March 2012 interim report**
Finland-based contractor Poyry released its first interim report of 2012 last month. The firm noted a slow start to 2012 but did not change its outlook for the year. Net sales increased by 16.4 per cent on the year before, up to USD 276.7M. Operating profit was USD 8.2M. A Poyry spokesman said that this was due to success in the urban and industry business segments, as energy and management consultancy fell.

▼ **Brenner modelling and services tender invitation**
Tender for engineering services to support project preparation and development of numerical modeling for underground structures in the Brenner base tunnel. Tel: +39 0471 0622-10 before 15 June.

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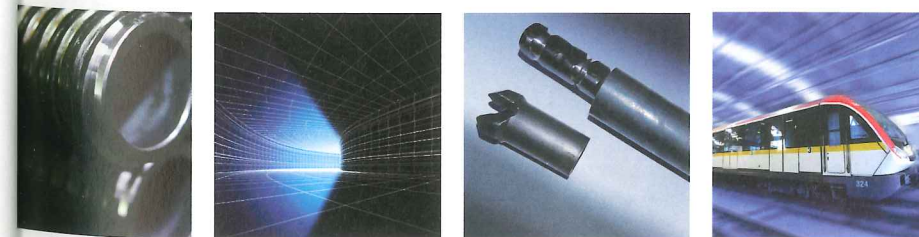


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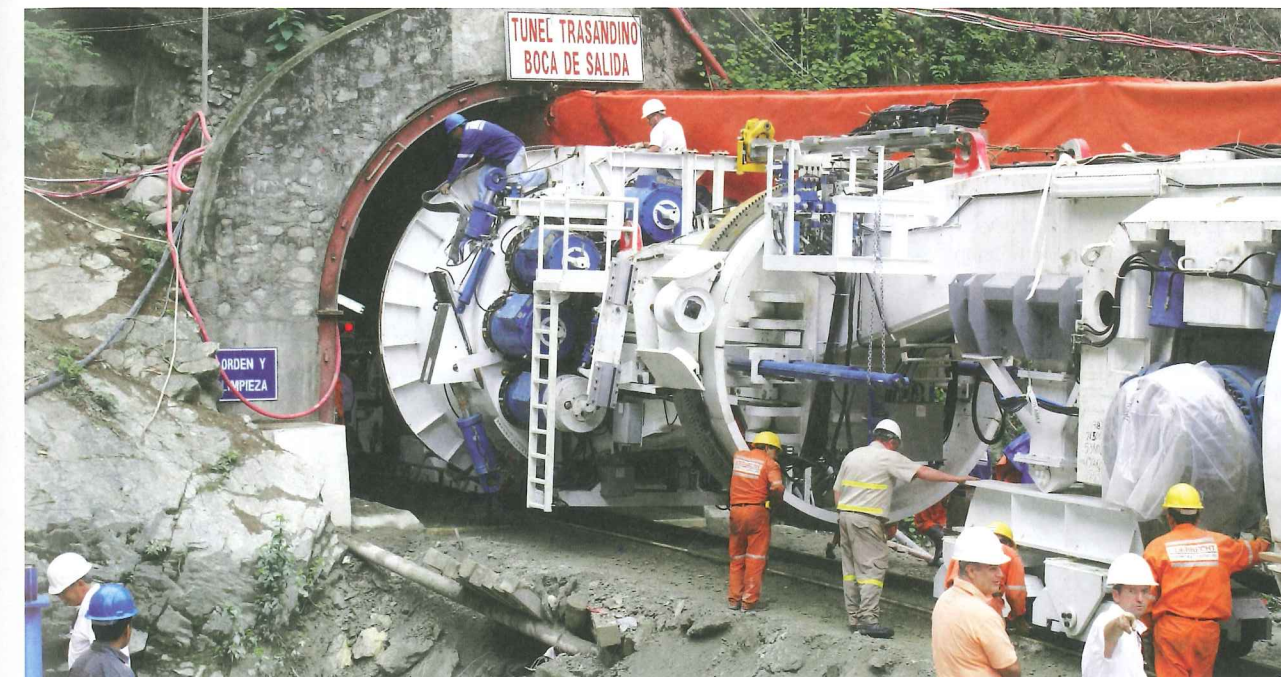
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The Latin dawn

South America is one of the waking giants of the global economy, with some analysts suggesting that a future Brazilian superpower could already be rising. Alex Conacher speaks to Rolando Justa, boss of Robbins' new Chilean office as he sets up shop in the Latin continent



"In Europe the market is dropping. China is the clear leader for tunnelling in the world and the rest of Asia is strong. Here we are growing – fast. In maybe five years South America will have surpassed Europe for tunnelling demand and there is work for everyone."

So says Rolando Justa who was brought in by Robbins last August to head up the company's new office in Chile. His official statement on the opening of the office explains that "setting up an office in this region was important to us because a close and constant approach with our clients is essential in the Latin American market."

Location, location, location

"We looked at the South American market carefully for a length of time to decide where to locate our base of operations. We have great expectations for Chile, though it was a very difficult choice between Chile and Brazil. There were similar opportunities from both countries that we set out as the two main opportunities for us.

"In the end, we reasoned that Chile (and nearby Peru) will have more hard rock projects, which we have a lot of experience

with and are more likely to win.

"There are big plans in all these places that we know are coming up. We expect around 50 to 60 per cent of tunnelling demand for us will come from Chile, and the rest will mostly come from Brazil with some from Argentina."

Justa adds that they are expecting work from every mainland country in the continent – though not from among the Caribbean Islands.

Going native

The region's community is culturally similar to what you find in Spain, and Justa stresses that you have to be faultlessly honest in your dealings or risk success.

Decision making takes longer, with everyone having to have their say, and there is in general a scrupulous adherence to proper procedure. Justa adds, "Here everything is very 'proper' and the way things are done, you have to follow all of the necessary steps through procedure. To get round this, or at least reduce the impact on you, you have to be in more contact with clients and also be ready to act on a moment's notice when you get the chance.

"This is actually the problem construction faces for the 2014 Fifa World Cup in Brazil. Some of the projects that were meant to be finished in January will probably be delayed until September because of this."

Justa says, "Another important consideration for the machine manufacturers in this part of the world is complete support for the project solution. That is to say, anyone can build a TBM and ship it out and leave it at that. To be successful we have to include the complete field support; provide training programmes for the operators; offer advice, for example on segment moulds and trailing stock and in general we are expected to bring to the table reports, ideas and proposals.

"A contractor or client expects you to know about the whole job, and to win you need to prepare a complete package."

Setting up shop

On his own operation, Justa says that they currently only have two fixed and two temporary people and as T&T goes to press, are not providing field support. He expects the office will be fully operational in June, with field support towards the second



half of the year. Justa says, "Things are going to move quickly once we start training the new guys."

The projects

Metro projects are in demand in the region, Sao Paolo in Brazil being a major one, but hydropower is expected to be one of the biggest drivers in the industry.

Mine work with TBMs is also increasing. Justa says that in mining Robbins is looking at main access and ventilation work.

Rail accidents caused by motorists attempting to rush through active level crossings in Buenos Aires has spurred political will into pushing through stalled projects to place the rails underground.

Power plants, especially hydroelectric are appearing more and more in South America, in Chile especially there are big movements in this sector in the capital, Santiago, amid some local unrest.

Justa adds that the private sector leads demand for projects in Chile. This is in contrast to the global industry which, according to a recent *T&T* poll, is seeing the public sector as the major driver. In the poll 76.2 per cent of tunnellers voted that the public sector was the major driver in their region. A commenter from Asia says that most hydropower work in their region is public, and a North America based tunneller noted that less than 10 per cent of major tunnel work in that area is from the private sector.

Olmos

The 12.5km-long Olmos trans-Andean tunnel drive was executed by Odebrecht with a 5.3m-diameter TBM and completed on 20 December 2011. Over 16,000 rock bursting events were experienced with 17 per cent classed as 'severe'. Geology of andesite, dacite, tuff, schist, and pyroclastic breccias up to 250MPa UCS was unforeseen and required in-tunnel machine modifications as rock bursting became more severe.

Crews removed the roof shield fingers and installed the McNally support system. The system consists of steel slats anchored to the roof of the tunnel by steel straps and rock bolts, effectively containing loose and unstable rock. These steel slats form an umbrella that allows the crew to work in a safe environment.

See *World at a Glance*, *T&T* February 2012, page 6 for more.

El Emisor Oriente

The Emisor Oriente is Mexico's largest infrastructure project comprising a 62km-long, 7m-diameter wastewater pipeline to



Above: Metro makes the first link in the tunnel excavation for the expansion of Line 5-Lilac. The connection is near a service pit

prevent flooding. Geology has been complex, including abrasive basalt, volcanic rock and high water pressure.

"Emisor Oriente is a big project. I think this is the most interesting EPB project you can find," says Justa. "Metro work is nothing compared to this. You've got up to 155m deep shafts [12 or 16m diameter], vertical conveyors and a third machine should be launching in the next couple of months." For a full article on the project by Robbins' vice president Joe Roby and Mexico general manager Roberto Gonzalez, see *T&T* December 2011, page 22.

In this report

Mexico City's first metro line in a decade finishes tunnelling below an urban centre that is sinking at a rate of 60mm per year; the lahar volcanic rock in Panama proves challenging for TBMs on hydro bores; and the Cheves hydro project in Peru contends with extremely varied ground.

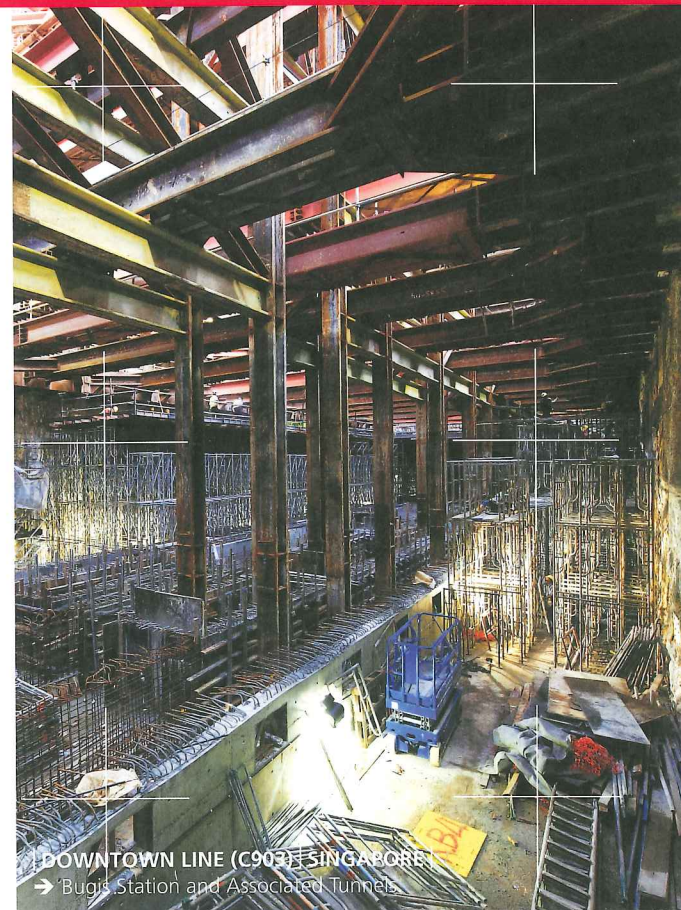
This issue of *T&T* also carries a report from the British Tunnelling Society's February meeting, in which the details of the San Jose mine rescue operation in Chile in 2010 are given a new angle. The report is presented by mine rescue expert Brian Robinson.



BUILD ON US



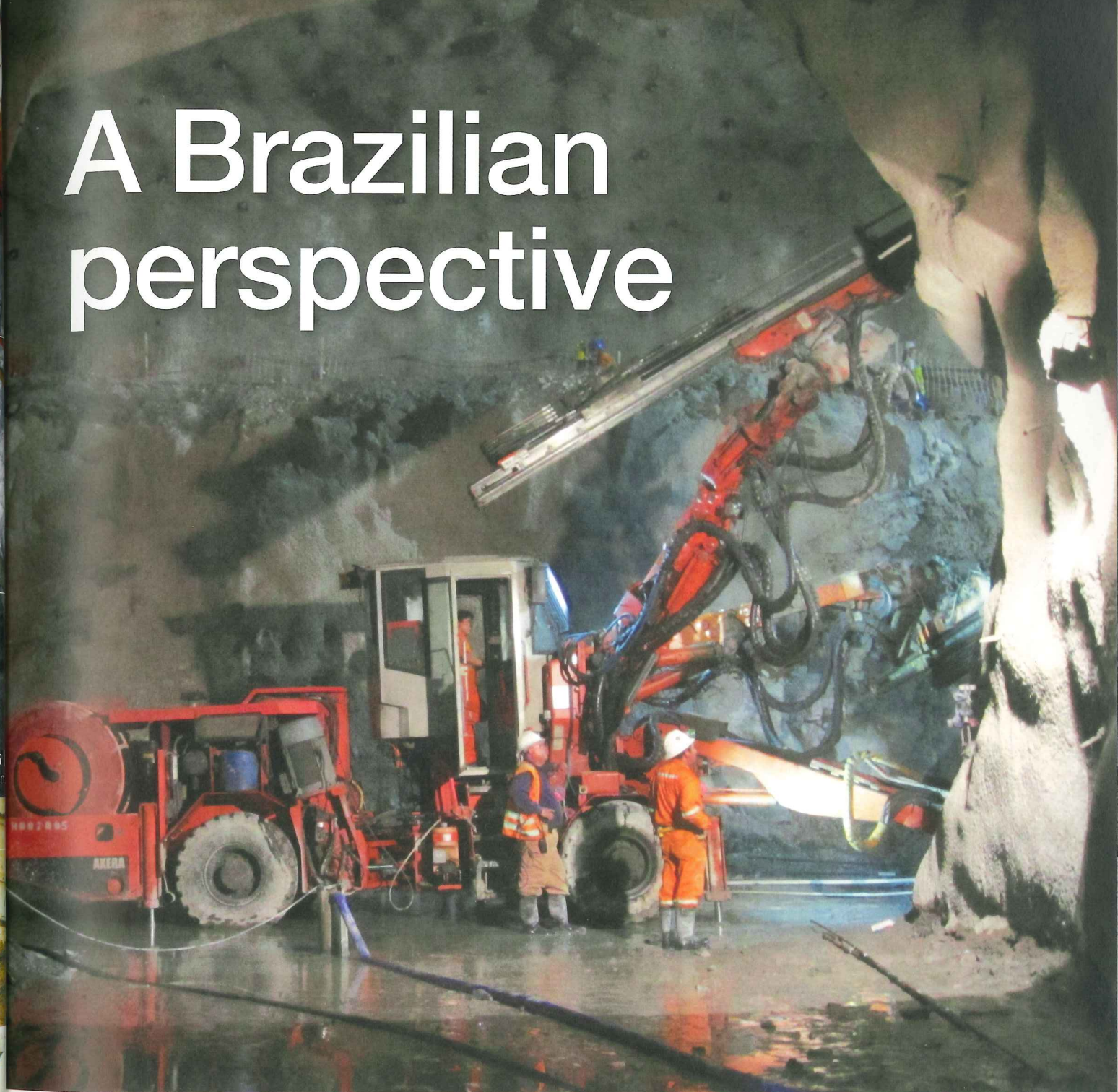
| MTRC WEST ISLAND LINE CONTRACT 703 | HONG KONG
→ Ground frozen tunnel for the removal of underground obstruction



| DOWNTOWN LINE (C903) | SINGAPORE
→ Bugis Station and Associated Tunnels



| CHINA LIGHT & POWER PROJECT | HONG KONG
→ Construction of a cable tunnel at diameter 3.2m



A Brazilian perspective

Focusing on Brazil, the largest economy in Latin America and the recent host of the Third Brazilian Congress on Tunnels and Underground Structures, Alex Conacher speaks with Hugo Cássio Rocha, president of the Brazilian Tunnelling Committee

Tell us about your work when you are not acting as president of the Brazilian Tunnelling Committee

I have worked for Sao Paulo Subway Company for the past 25 years. I am a technical advisor on project management and right now am advising on four metro projects: Line 5 (lilac) between stations Adolfo Pinheiro and Chácara Klabin, with 11km of extension; Part two of Line 4 (yellow) with

1.5km of tunnelling and four new stations; Line 6 (green) with 15.5km of tunnelling; and Line 15 (white) with 13.3km of tunnelling. In total it amounts to 62km of underground works.

On top of this the company is working on Line 20, between Lapa and Moema, adding another 12.3km. In addition there will be 31km of monorail lines, giving a total of some 100km of tunnelling on the metro.

Where are tunnellers finding work in Latin America?

Venezuela has an ambitious plan to install metro in Caracas and Los Teques. Santiago, in Chile, and Buenos Aires in Argentina are also building metro lines.

Then there are the 'Transandinos' [trans-Andean] base tunnels. Besides this, many other works in Colombia, Ecuador and Peru are underway.

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In Brazil, we have projects in Sao Paulo, Salvador, Fortaleza, Curitiba, Porto Alegre, the TAV-high-speed rail project between Rio de Janeiro and Sao Paulo, and particularly a lot of work related to the World Cup in the main cities, and also the Olympics in Rio de Janeiro.

Many other underground projects are being carried out to install major mining and power generation infrastructure. For example, the Anglo Gold Mining Company works on about 20km of tunnel every year to explore mineral deposits.

It is difficult to measure where you can find the most tunnelling work, but I believe that in Brazil it would be the urban areas between Rio de Janeiro and Sao Paulo.

Is the political climate favourable to tunnelling?

Yes, the current situation is favourable to tunnelling. The Sao Paulo Metro, for instance, has had an investment of around USD 10bn dollars up to 2014 and a further USD 15bn post-2014.

This is an important time for infrastructure and, considering the huge urban concentration of population, people tend to choose underground solutions.

In infrastructure the investments come mostly from the government, but in areas such as mining and power generation, there is more private investment.

What are the biggest achievements in recent years?

It is something that is very difficult to measure, but we can highlight a section of the Imigrantes highway, connecting the city of Sao Paulo and its coast, crossing the Serra do Mar mountain ranges.

This project overcame a 700m stretch of complex geology using three long NATM tunnels of about 3km each and reducing the impact on the state park and world heritage site of Serra do Mar.

Two other great achievements were the success in using the first large diameter EPB TBM to build Line Four – Yellow, of the Sao Paulo Metro, and the first Rock TBM in Brazil, which built the 5km Gastau Tunnel from Petrobras, again crossing Serra do Mar with low environmental impact.

What have been the greatest disappointments for the industry in the past year?

I believe the biggest disappointments have been related to budget. Where projects have run into unforeseen costs and gone over budget.

Besides this, accidents, such as the one at Pinheiros Station on Line Four of Sao

Hugo Cássio Rocha



Hugo Cássio Rocha is a graduate of geology with a master's degree in civil engineering. He also has an MBA in management. He has worked for the Sao Paulo Subway Company: 'Metro' for 25 years as the technical advisor to project management. He is also the president of Brazilian Tunneling Committee.

Paulo Metro, causing seven deaths, make managers of these projects insecure.

What is the geology like in the region and which construction methods are generally preferred?

For all types of geology, the most used method is conventional tunnelling or NATM, but in the last few years there has been a great increase in the use of TBMs. The trend is to use TBMs in urban areas and long tunnels.

In short tunnels of variable section through rock, NATM will still be used for the next few years. The use of TBMs is growing especially fast in Venezuela, where mechanised equipment is now in widespread operation.

What are the main challenges to the industry in Latin America

The main difficulty is the lack of state of the art equipment available and also the lack of specialised engineers.

In Brazil, taxation is responsible for many difficulties relating to modern equipment. Regardless, some important companies are coming to Brazil. One example is Herrenknecht, which has announced a new factory will be built in the country.

Another difficulty is the lack of knowledge, internationally speaking, of the behaviour of the kinds of soils in tropical regions, where there are many rock changes. This kind of soil is almost non-existent in the northern hemisphere and because of this there is a lack of research about its behaviour and facing the demands of underground excavation.

How does the future look for the tunnelling industry?

There are many problems with infrastructure in South America. If the economy maintains the current rhythm of growth, led by China and the BRICs, there will be much employment and many opportunities for specialised people, equipment and input suppliers.

The tunnelling industry is buying modern equipment such as hidromills, boomers and TBMs, because, as I mentioned, Brazil is starting to attract factories.

It is argued by some in the region that Latin America is one of the most promising markets for future work. How do you think the region compares with the rest of the world?

China is the market of the moment, above both Africa and Latin America, and also the Middle East. Africa still needs a lot of development before it reaches the maturity of Latin America. The Middle East markets have reached a plateau of reliable workflow. Leaving Latin America at the next frontier with a rapidly developing market a sustained drivers of demand.

Are there any parts of Latin America that are not enjoying the boom in tunnelling work?

I believe Paraguay is the country where there is the lowest potential for tunnelling, both because of its economy and its topographical conditions.

What are your greatest concerns for the future of tunnelling in Latin America?

Probably, the block on the growth of the industry here is the lack of professionals specialised in all engineering areas: geological engineering and specialised technical disciplines. After many years of stagnation in civil engineering, many professionals have left the area, and the graduation of the next generation of engineers takes at least four years.

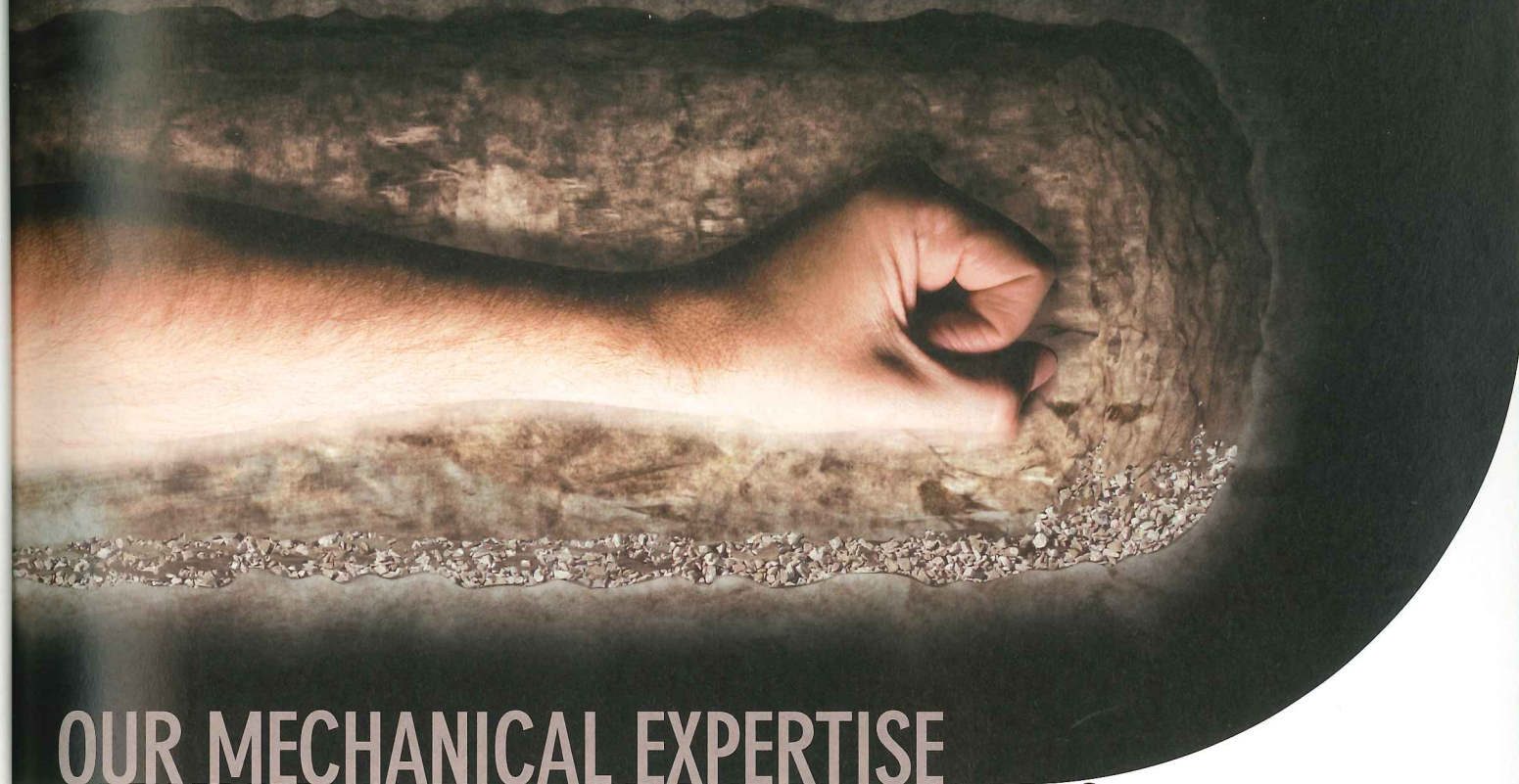
Another concern is the European financial crisis, which causes recession and reduction in investments.

Any other thoughts?

I would like to be starting my career today, so that I could have the opportunities that are approaching for geological engineering applied to underground works.

When I finished my graduation course some 30 years ago the market was stagnant. Opportunities were very few and there was no hope for the future. Today, it is totally the opposite. I believe we will have at least five or 10 years of high growth. ■

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Lines in lahar

The neighbouring bores on the Pando-Monte Lirio-El Alto hydro cascade scheme in Panama were set to present the possibilities for unusual challenges for TBMs. The geology consists of highly variable lahar volcanic rock, an uncommon barrier for shields to penetrate. There was potential for quite different experiences within as well as between the drives, and that has proved to be so as excavation has started.

Where the lahar so far has been good, on Pando, there has been the benefit of consistent progress for tunnelling contractor and TBM manufacturer Seli in the west of the country.

The Italian firm supplied three TBMs and crews for the three projects in the Chiriqui Viejo Valley where Pando and Monte Lirio are being built just upstream of El Alto, which has a different developer (see figure 1, below). All three projects are being constructed under very long, 50-year, concessions, awarded by Autoridad Nacional de los Servicios Públicos (ASEP).

Seli supplied three mixed-face EPBMs under two separate contracts for the projects, which will see a total of almost 16.5km of tunnel boring through lahars.

Further downstream, another hydropower plant in the cascade in the early construction phase is Bajo Frio, which is being developed by Credicorp and Aqua Imara, which formerly had the name of an SN Power subsidiary and is majority held still by the firm. They are operating as Fountain Intertrade on the project.

However, because the topography in the lower reaches of the valley opens out so much, no more underground works in

lahars are called for.

The lahar tunnelling challenges are upstream in the tight, snaking valley. However, Seli has other tunnelling work in the area, being called in as part of a group to help repair a tunnel collapse on the Esti hydropower project (see box, page 28).

The trouble with lahars

Volcanic rocks are always a challenge but lahars especially so. They derive mainly from volcanic slurries and can contain significant amounts of water, depending on the local geology and hydrology. They can be formed due to eruptions – flows or explosions – or seismically-induced shifts and mixing of the ground.

As mudflows with such different possible origins, the slurries have quite varied characteristics which further change with progress of the flows, both dropping out material as well as gaining inclusions. Then, solidified, each flow is termed a lahar, and the properties of each matrix are highly varied, even locally.

Prior to excavation, the local lahars in Chiriqui Viejo valley were classed into two types: matrix- and clast-supported. There was no information then to help split classification with respect to cohesiveness.

The lahars showed uniform residual and peak friction characteristics. There were also groundwater risks, depending on insufficient fines in the mix or water-bearing strata being met. Generally, permeability was seen as low in at least the matrix-supported rock which was the poorer in terms of fines and less well graded of the two classes.

Mix at Pando-Monte Lirio

Awarded an engineering, procurement and construction (EPC) contract for the Pando and Monte Lirio underground works in late 2009, Seli is constructing a total of 13.1km of headrace tunnel for the schemes which are being developed by Electron Investment. The projects are to be commissioned by the end of 2013.

The Monte Lirio project has the larger of the two tunnels – almost 7.9km in length with a finished diameter of 3.2m. The tunnel will link Monte Lirio with El Alto to the west. The tube is being bored by a 3.92m diameter EPBM, and the lining comprises 1.2m-long rings constructed of 250mm thick precast concrete segments in a five plus one arrangement. Spoil removal is by locos and wagons.

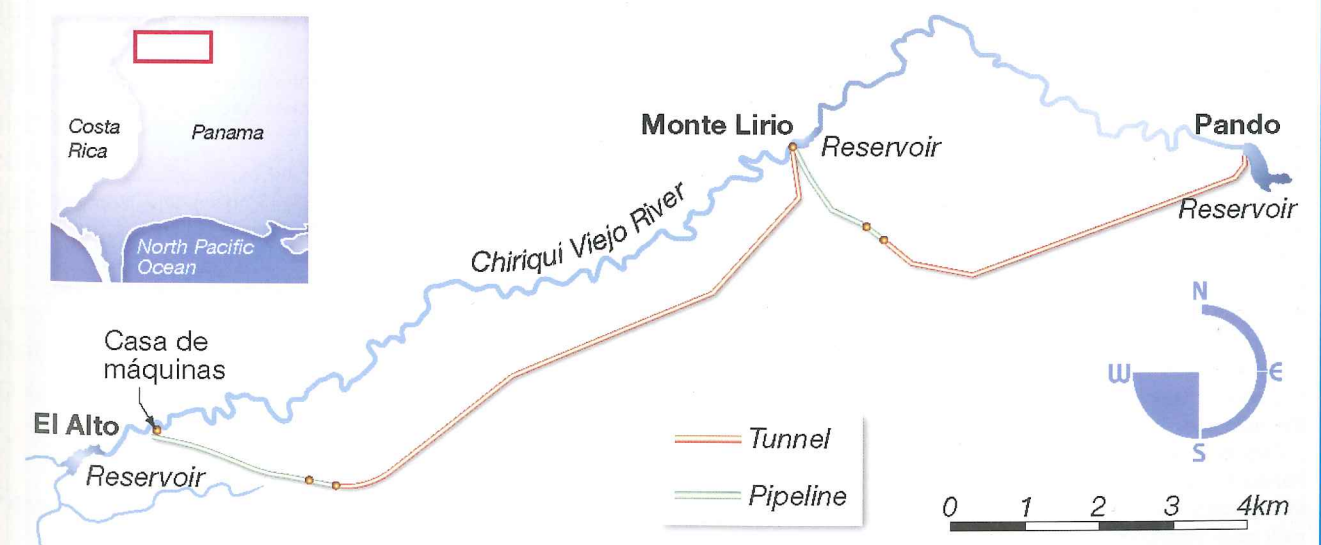
Despite a positive start in early 2011, the TBM soon met with difficult wet ground conditions and advance rates slowed. In one period of two and a half months it had advanced approximately 780m.

Shield standstill

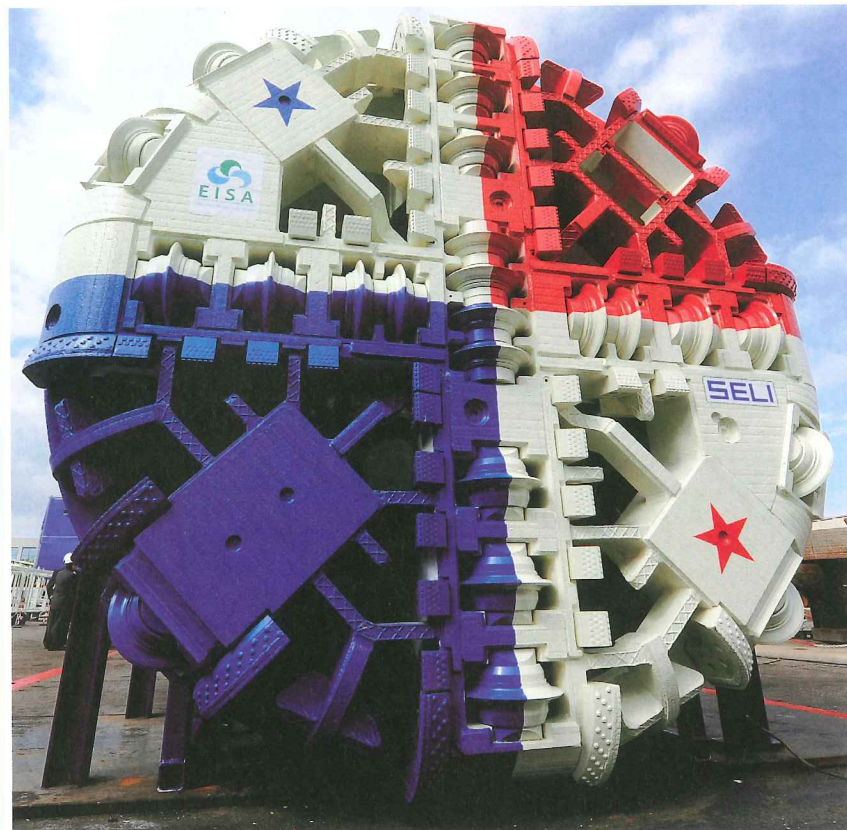
Encountering loose lahar and large water inflows, the machine was stuck, it adds. Seli says that a top heading of approximately 20m in length was excavated to free the shield. The cutterhead had been trapped by a large, uncemented boulder and there were significant inflows, "recognised by the geologists as unforeseen ground conditions," according to Seli.

After four months of standstill the drive was able to continue late last year. By the beginning of this year the EPBM had constructed 1,550m, or approximately one-

Above: Figure 1, Lahar TBM challenge at Chiriqui Viejo upper hydro cascade, Panama



The lahar volcanic rock of west Panama proves a tough mix in TBM bores for hydro projects, reports technical journalist Patrick Reynolds



Left: EPBM for Monte Lirio headrace bore in lahar volcanic rock

fifth, of the headrace.

For the Pando project, Seli supplied a 3.72m diameter but otherwise virtually identical EPBM with 17 inch discs as well as rippers on the cutterhead. The TBM is driving an almost 5.2km long headrace of 3m i.d. but with the same arrangement of lining. The bore will link Pando with Monte Lirio in the west. Spoil removal is by the same method as the Monte Lirio project.

The TBM set off early last year and met with a cemented portion of the headrace tunnel, enabling it to achieve good progress, encountering few difficulties until near the end of 2011. By October, and including the learning curve, the machine had achieved a 1,600m advance in some five months.

However, at the end of the year, the first notable problem was met. This was 'very similar' to that encountered at Monte Lirio, says Seli. Part of the work performed to get through the problem included consolidating the front face and draining the groundwater to reduce pressure. By then, the machine had bored 1,900m, or just over a third, of the headrace.

Over both projects, Monte Lirio and Pando, the ground conditions met ranged from good to poor. Where it was good, the rock mass was tough at the face, holding

groundwater. In those sections the drive progresses with full pressure face control.

On the projects, the EPC contractor for the main civil works is Cobra.

El Alto experience

Under construction down the valley, the El Alto hydropower plant will also have extensive underground structures for the relative scale of the firm power of the scheme. The prime structures are the 3.24km-long headrace plus the surge tanks, a 96m-high shaft and the penstock of just over a third of a kilometre in length. El Alto is being developed by a JV of Hydro Caisan and Panama Power Holdings.

Scheduled for commissioning next year, excavation of the El Alto headrace began in the third quarter of 2011. A 6.79m diameter EPBM was ordered from Seli under another EPC contract.

The crew driving the EPBM have had a challenging time taking the TBM through loose lahar from the outset. The particular mix of lahar strata is made up of rounded blocks of uncemented rock and there is "considerable water pressure", says Seli.

However, it notes further that otherwise there have been no major problems on the drive. By the beginning of 2012 the machine had constructed 970m, or approaching a third of the length of the headrace tunnel.

Early in the drive, the machine advanced 350m in three months, which includes the learning curve as well as necessary pauses for installation of a continuous conveyor belt for spoil removal. ■

highly cemented basalt boulders and having low permeability, which allowed tunnelling with only minor difficulties.

But, where it is poor, the mass is loose with uncemented small stones, gravel and sand with accompanying large inflows of

Esti repairs

Seli is also operating in west Panama, in the Chiriqui region, to help with tunnel repairs at the Esti hydro project which is owned by US energy group AES. The repair works on a collapsed section of the headrace are being undertaken with joint venture partners Lombardi and Obras Subterranas.

Built almost a decade ago, the Esti plant has been out of action since late 2010 due to the problem, and the JV is expected to have the repair work completed around the middle of 2012. The work is being undertaken on a design-build basis.

Recovery works in the 9m wide tunnel have used a number of adits to remove the collapsed material and then repair the affected parts of the 4.8km long structure. Sprayed concrete lining has been used for the affected sections but the entire length of the headrace is to then be lined with cast in-situ concrete.

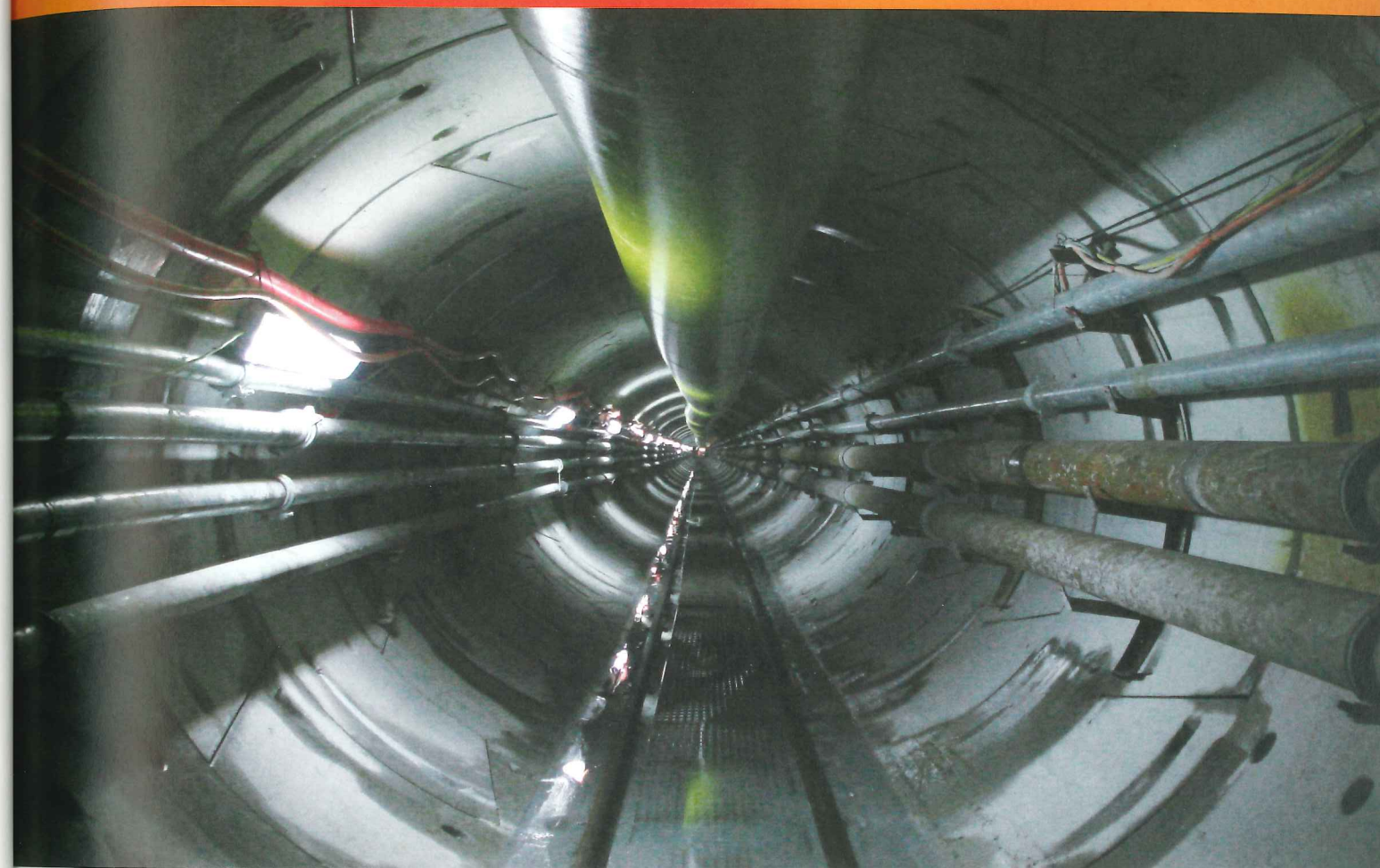
The plant was taken out of production a year and a half ago to allow for investigation of the tunnel problems, which were greater than initially expected. Norconsult helped to investigate the collapse and, following those further studies, the client signed the contract with the Seli-led JV in mid-2011 to perform the recovery work.

Esti is a run-of-river scheme and is owned and operated by AES subsidiary AES Panama. It is a key generation asset in the country.

The project was built over 2000-2003 under an EPC contract by Consocio Esti, which included Skanska International Civil Engineering, GE Energy (Sweden), Alstom Power Generation and SwedPower International.

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Above: While much of the route was deemed unsuitable for underground excavation, the 7.7 km long section below the densely populated heart of the city was excavated using a Robbins EPB.

Parting the crowd

At more than four hours per day on average, commuters from the southern neighborhood of Tlahuac often spend much of their time in buses and cars travelling to and from work in the downtown area of Mexico City. That will change later this year, when Line 12 will open between Tlahuac and Mixcoac areas, cutting commute times by more than 2.5 hours. Up to 437,000 daily passengers are expected to ride the rails, making it the fourth busiest line in the system.

To speed the project schedule, construction of the line was divided into two phases: above ground and below ground. The metro line goes below ground where the geology is less rocky. Opting for TBM tunnelling had the advantage of minimising disruption on surface streets. Combining TBM tunnelling, cut and cover, and elevated track, minimised tunnel construction time allowing the project to stay within budget. In 2009, the contract was awarded to the ICA consortium, consisting of ICA, Carso, and Alstom for construction, and for tunnelling with a 10.2m diameter Robbins EPBM.

Evolving geology

Tunnelling is located in the complex geological strata of the Valley of Mexico, which was founded on what was once an island in the middle of Lake Mexico, then subsequently drained. Geotechnical investigations of the metro tunnel area showed an abundance of lake clays, interspersed with sections of sand, gravel, and boulders up to 800mm in diameter.

Long dormant and eroded volcanoes are buried throughout the area, where they have deposited volcanic rock and fields of boulders in the lakebed.

The geological profile for the Line 12 project indicated a large variation in the conditions along the tunnel length. The initial portion of the excavation was relatively homogeneous, consisting primarily of sensitive, watery lake clays. In particular, the first half of the tunnel consisted of very soupy clays with up to 75 per cent water content.

"We decided on an EPBM after analysis of the geotechnical data, which showed that soft clays were predominant," said Benamar.

The final portion was more heterogeneous, and included several sections of compacted sand, pebbles, boulders, and clay. A high percentage of boulders was expected, with diameters up to 800mm.

The variation in conditions required initial muck removal using a sludge pump for the clay, which was changed out with muck cars after passing through Eje Central Station as the ground became harder.

EPBMs are capable of handling the mixture of soft ground with large boulders, and the design required several specialised features. These included a two-stage screw conveyor setup with an initial 1,200mm diameter ribbon-type screw conveyor.

High population, low cover

In March, Mexico's sinking capital finished tunnelling its first new metro line in a decade. Robbins technical writer Desiree Willis reports

One look around and you'll notice that nothing in Mexico City is static: the flow of buses, bicycles and cars is non-stop while pedestrians crowd the sidewalks. Not even the ground is constant—in this sinking metropolis built on lake clays the earth settles about 60mm lower per year. Building a tunnel in this uniquely dynamic environment is no easy task, but the Mexican Federal District was undaunted by

the challenge.

In 2007, the project owner laid the groundwork for the country's first new metro line in a decade: the 25.4km long Mexico City Metro Line 12, to be completed in 2012. The new route, also called the 'Gold Line', would be the longest in the metro and include 7.7km of mixed ground TBM tunnelling with eight underground stations.

Everything about the underground

portion of the project was designed around the concepts of limited space and potentially unlimited movement. "The stations were built into bedrock, while the tunnel lining itself is quite rigid. Special structures connecting the station with the lining allow long-term ability to absorb some of the settlement by offering some give," says Ismail Benamar, tunnel manager for the majority of TBM tunnelling with contractor Ingenieros Civiles Asociados (ICA). The dynamic project has been well planned from TBM assembly through its completion on 1 March 2012, making it a standard for urban tunnelling in complex conditions.



Above: The 10.2 m diameter Robbins EPB is the largest TBM ever to bore in Mexico



Above: Custom segments were manufactured 24 hours per day by contractor ICA, then trucked daily to the small station sites

Large pieces of material travelled up the center of the screw to exit out of the boulder collecting gate, while more fluid muck continued on to the secondary shaft-type screw conveyor for conventional removal by machine belt conveyor.

Conditioning of the variable ground was dealt with using additives injected through six independent ports in the cutterhead. The independent lines consolidated the flow of muck and reduced the risk of clogging, which can lead to uneven wear of the cutterhead and cutting tools. While the watery clays did not need additives other than water from the sludge pump, the cobbles and boulders encountered later required the use of foam additive. The foam, consisting of water, surfactant, and additive, aided in maintaining earth pressure and reduced the required cutterhead torque.

Big TBM assembly, small space

Prior to launch of the machine in February 2010, a big problem needed to be tackled: how to assemble the country's largest TBM in a jobsite the width of a city street, in a launch shaft only 14m wide and 34m long.

Because of the tight schedule and large machine diameter, Onsite First Time Assembly (OFTA) was used to initially assemble the TBM on location, rather than in a manufacturing facility. It was estimated that the assembly saved four to five months on the overall delivery schedule.

"OFTA has the benefit of no pre-assembly – everything was delivered directly to the site and assembled here. The assembly went very smooth, and it was a little over three months before we started to turn the

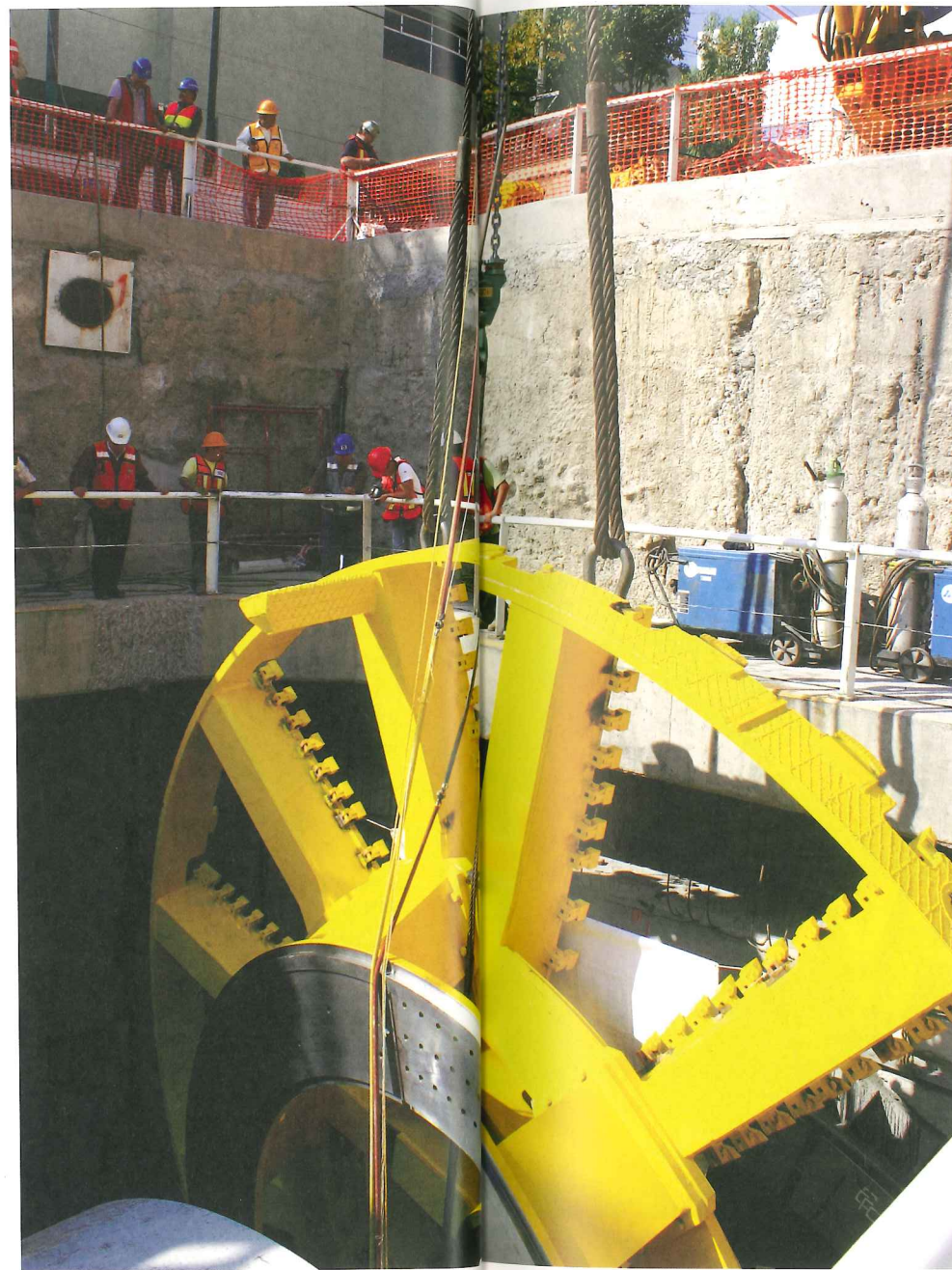
cutterhead and push the machine forward," says Ron Jelinek, Robbins field service technician.

Critical subsystems, such as the electrical and ventilation systems, were tested before being shipped to the jobsite. Multiple dimensional checks ensured precision components and proper fit up. These measures include inspection of all sub-suppliers, who had to use a template when manufacturing components.

Components were lowered into the 17m deep launch shaft for assembly inside a concrete cradle. Assembly began with 'inner core' components including the cutterhead support and screw conveyor. Then the upper and lower halves of both the front and rear shields were lined up with welding ports in the cradle, used as a space for crew members to weld the pieces together. The front and rear shields were connected by articulation cylinders for active articulation in curves. Machine components were not assembled directly on the concrete cradle, but on two rails at 60-degree angles. The rails were then used to push the machine to the tunnel face during startup.

Designing for movement

The project's location at the city center meant that from the start, sensitive structures were close by. The tunnel's low cover of between seven and 14m due to the depth of the stations, and the passage of the machine within 12m of a 16th century church, required an intensive monitoring program from TBM launch. "We have a real-time monitoring program to detect displacements and pore pressure on the



Above: The 10.2m diameter Robbins EPB was assembled in a little over three months in a small jobsite the width of a city street

surface, underground, inside the tunnel, and in the most critical structures next to the tunnelling line," says Benamar.

During tunnelling the TBM also passed within 1.5m of a 4m-diameter collector sewer, within 2m of building foundations, and just 3.5m below the metro's active Lines Two and Three. At one point, the tunnel also passed between two supports of an existing freeway bridge, with about 4m of

distance between the TBM and bridge pile foundations. High pressure water pipes responsible for 25 per cent of the city's supply ran parallel to the tunnel for 800m with about 6m of separation.

All were navigated successfully with a combination of monitoring and effective tunnelling – no jet grouting was used around the structures.

"The settlement stayed within the 20 to 50mm limits throughout tunnelling, keeping in mind that annual settlement in the city is 60mm per year. Our surveyors had to update their data points every two to three months because they kept moving due to



Above: Despite numerous planned stoppages through each station site, the Robbins EPBM achieved rates of up to 135m in a week, and managed 400m per month on average

citywide sinking. We placed some reference points in the bedrock to allow for correction," explained Benamar.

The risk of surface subsidence and vibration was controlled during excavation by regulating the rate of advance and controlling earth pressure at the front of the machine, as well as the backfill grouting pressure. The contractor was able to decrease the machine's rate of advance using variable frequency drives in sections close to sensitive structures. The EPB cutterhead rotation was also kept low throughout the excavation, at a maximum of about 1.5rpm.

As the machine advanced, the tunnel was lined with 400mm thick universal concrete segments in a 7+1 arrangement. A two-liquid back-filling system was used to quickly stabilise the annular space between the tail shield and concrete segments. The liquid mixture consisted of water and bentonite cement plus an accelerant, which were combined in the tail shield to harden rapidly after injection.

Segments and stations

The segments and stations themselves were designed to withstand the expected long-term settlement of the city's soils. "The lining is quite rigid because the stations are fixed and the diaphragm walls are driven into the bedrock," said Benamar. The first half of the tunnel in soft clays is expected to experience greater settlement, so the rebar-strengthened segments in this section are more heavily reinforced and a secondary concrete lining will be added in



the coming months.

The custom segments were manufactured 24 hours a day by ICA about 30km from the jobsite, then trucked in, as the small stations only had the capacity to hold about 1.5 days worth of segments.

Most stations were built 2 to 3m below street level, and were excavated as box culverts using diaphragm slurry walls. Windows were cut into the diaphragm walls as the entry and exit portals for these machines, and material around the windows was replaced with cemented ground for greater stability.

Breakthrough, times seven

One of the most unique aspects of the project was the multiple intermediate breakthroughs as the machine entered and exited seven cut and cover station sites (plus the launching site for a total of eight stations). Distances between the stations ranged from as much as 1,800m to as little as 400m, while the stations themselves were between 150 and 190m in length. Each time the launch site was moved forward, storage areas were moved forward to that station site as well, including settlement ponds for the sludge pump while it was used.

"Every time, the machine spent about one to two months in the station in order to rebuild launch structures, do maintenance on the machine such as cutterhead inspection, walk it through the station, and transport the supplies to the next site," said Andrei Olivares, project manager for Robbins Mexico. The EPBM was supported on a concrete cradle and walked forward using a thrust frame and pushed off of free-standing rings between the tail shield and thrust frame. Entrance and exit seals in the diaphragm windows were used to avoid any voids or settlement as the machine moved from station to station.

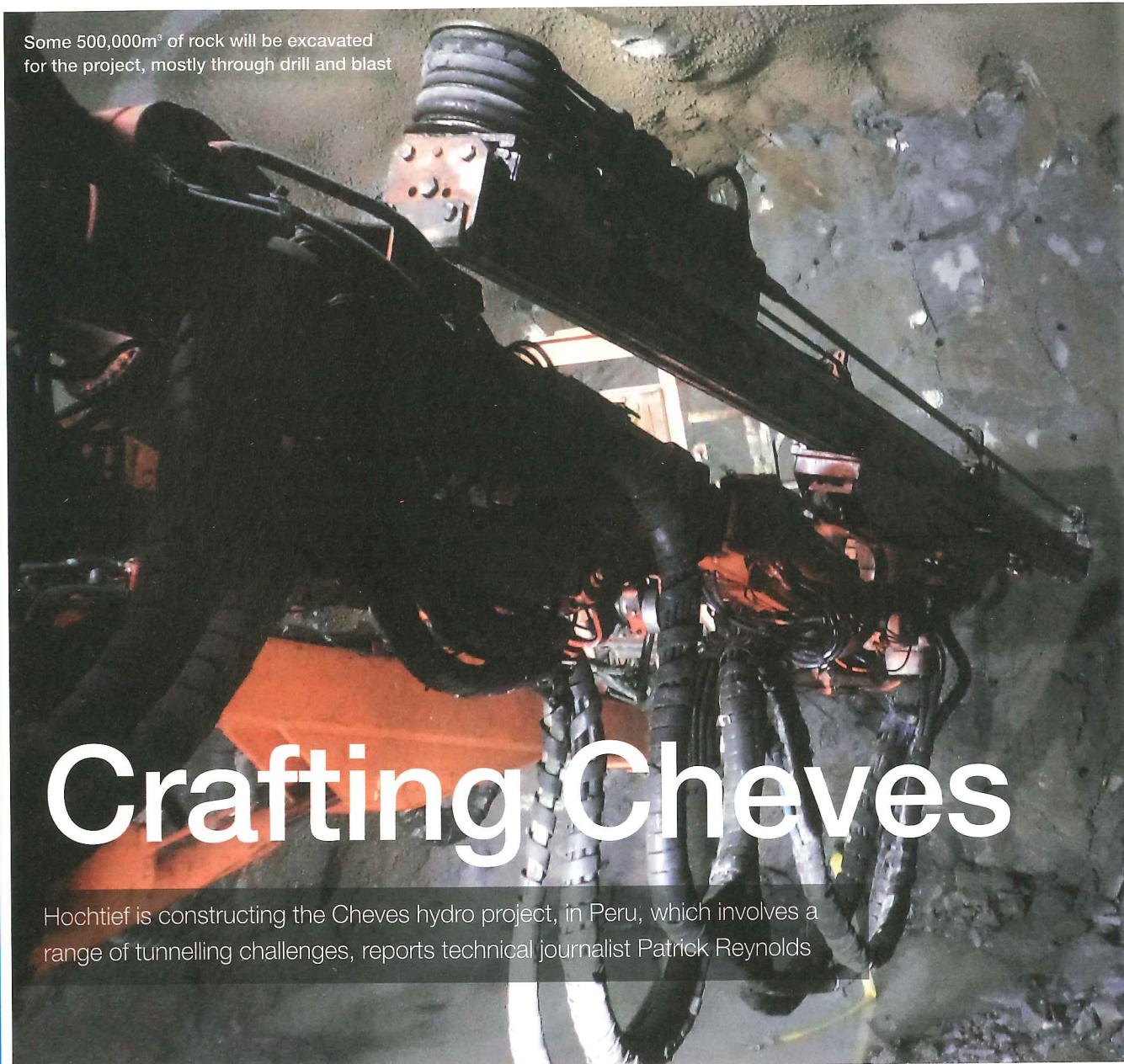
Olivares was pleased with the TBM performance and the maintenance of tunnel alignment during excavation: "The TBM guidance system tracked through curves, and the active articulation allowed us to negotiate curves as small as 250m in radius. The overall alignment of the tunnel finished up perfectly."

Despite the numerous planned stoppages, the TBM achieved good advance rates of up to 135m per week. By the time of the machine's final arrival into Mixcoac station on 1 March, the TBM was averaging 400m per month.

As of March 2012, construction is wrapping up on the secondary lining, and the entire Line 12 is scheduled to open by the end of this year. ■



Some 500,000m³ of rock will be excavated for the project, mostly through drill and blast



Crafting Cheves

Hochtief is constructing the Cheves hydro project, in Peru, which involves a range of tunnelling challenges, reports technical journalist Patrick Reynolds

Drill and blast excavation is making steady progress in the early phase of underground works on the Cheves hydropower project, under construction in the Andes mountains of Peru. The contractor, Hochtief, leading JV Constructora Cheves, has excavated the adits and access tunnels at key areas of the 9.7km-long headrace, including the surge tunnel, the powerhouse where the crown has already been opened up. It is blasting from the lower section of the 3.3km-long tailrace as well as both ends of the transfer conduit between reservoir high in the catchment area.

The scheme is being developed by Norwegian power group SN Power, and work began in late 2010, a year after the agreement was signed with the government to build the scheme. With a scheduled start-up shortly before the end of 2013, the power plant will have been brought into operation within three years of work commencing on site.

By the middle of this year the rapid excavation of the powerhouse and transformer caverns should be complete, enabling fast progress for mechanical and electrical installation. Downstream of the caverns, the tailrace tube is due to be finished by early 2013 and, upstream, the

transfer and headrace tunnels are scheduled to be completed by the middle of 2013. A total volume of some 500,000m³ of rock is to be excavated for the project.

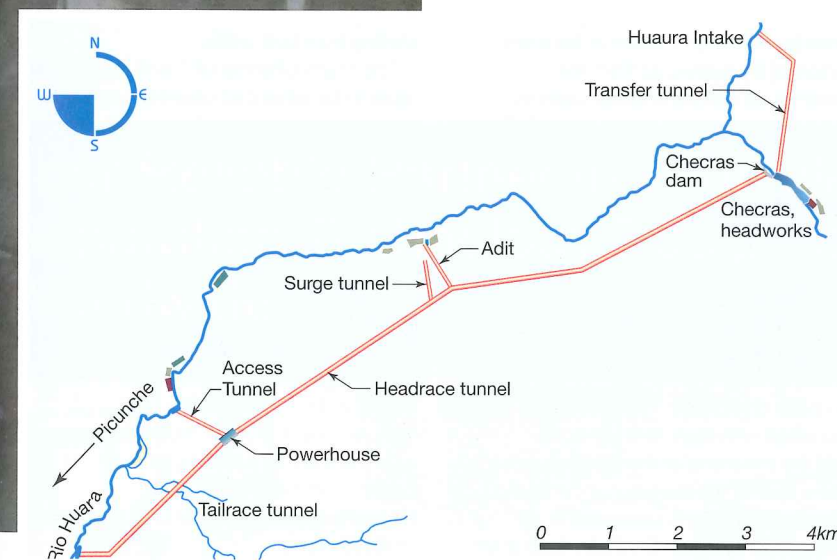
SN Power and Hochtief/Salfa worked together in Chile recently on the first phase of the La Confluencia hydro scheme, which has comparable installed power capacity and also called for significant tunnelling work to be undertaken by drill and blast.

Preparing for Cheves

Peru has seen a number of hydropower projects with underground works built in recent decades, and alongside Cheves others currently under construction or in

Below, top: Figure 1, location of Cheves HEP project in Peru

Below, bottom: Figure 2, layout of Cheves headrace and tailrace tunnels



preparation include Quitarcasa (92MW – Suez Energy), Huanza (90MW – Buenaventura), Chaglla (300MW – Odebrecht), Tam40 (1,286MW – Odebrecht) and Cerro de Aguila (500MW – Inka Energy). Cheves, on the Huaura River some 200km north of the capital, Lima, is the most advanced of the schemes currently under construction.

A high-head scheme, the 168MW plant is expected to generate up to 835GWh of electricity annually. The powerhouse cavern, one of the main structures on the scheme in Oyon province, Lima department, will hold two 84MW generating units. While primarily a power scheme, the

run-of-river project will see river regulation during the dry season.

SN Power, which wholly-owns the scheme, is developing the project through the special purpose company Empresa de Generacion Electrica Cheves.

Designer on the project is Norwegian consultant Norconsult. The main contractor and manufacturer is: Constructora Cheves a JV led by Hochtief (65 per cent) with Salfa (25 per cent) and Ingeniero Civiles y Contratistas Generales (ICCG) (10 per cent) to perform the civil works.

Hochtief and Salfa worked together on the underground works for La Confluencia, developed by SN Power with Australia-



based Pacific Hydro. Tecsca was the JV partner and last year was acquired by Salfa.

Other key companies, supplying the scheme, are Rainpower, ABB and Jeumont Electric for the electro-mechanical works; Abengoa Peru for the 75km long, 220kV transmission line; and, Cempro Tech for the hydraulic steel works.

The Government department overseeing the scheme is the Ministry of Energy and Mines (Ministerio de Energia y Minas).

Funding has come through the International Finance Corporation (IFC), which is part of the World Bank Group, and other banks, such as DnB NOR and Nordea Bank which have both supported SN Power capital investments before, and also West LB and Societe Generale. They are putting up USD 250M, which is the bulk of the funding as long-term debt finance.

Project layout

While the scheme features three dams, they are small and the underground works dominate the infrastructure, having a total of approximately 18km of tunnels.

In layout, the uppermost of the tunnels on the scheme is the 2,580m-long, 15.9m² horseshoe-shaped cross section transfer conduit between the Huaura intake on the main river to the lower, Checras reservoir on a tributary.

After passing through settlement channels to reduce the sediment load, the flow enters the 9,693m-long headrace tunnel, which has an upper section at a grade of two per cent and a lower section at 14 per cent grade.

At a constant width of 5.5m, the upper and lower sections have heights of 4.5m and 6m respectively, with their horseshoe-shaped cross sections having areas of 22.6m² and 30.1m² respectively.

At the junctions of the lower and upper tunnels will be an offshoot stub tunnel – the approximately 700m-long (30.1m² cross section) surge chamber, also with a 14 per cent slope.

The bottom end of the headrace tunnel splits into two short penstock tubes, taking the flow to the generating units in the powerhouse cavern (60m long by 32m high by 15.5m wide). The slightly smaller transformer cavern (27.5m by 14m by 11.2m) is immediately adjacent, and the large access tunnel reaches both.

Downstream, the flow is discharged into the 3,312m long (24.9m² cross section) tailrace tunnel.

In terms of volume, the largest underground structures are the headrace tunnel, which accounts for almost half of the tunnelling to be done, and then the



Right: Excavation through grandiorite for the crown of the powerhouse complex, which has an overburden of some 750m and requires 25,000m³ of rock to be removed

tailrace, transfer/diversion and access tunnels with totals of approximately 253,000m³, 81,000m³, 41,000m³ and 39,000m³, respectively, based on minimum cross sections.

Aside from the powerhouse and transformer caverns (24,850m³ and 4,400m³), the access tunnel holds the largest cross section of all the tunnels, at 41m² based on a height of 7.3m and a width of 6m.

Design and geology

The prime design challenges for Cheves were around geology, floods and sediment transport and seismic stability, says a Norconsult spokesman.

Geology in the area is extremely varied with sedimentary, igneous, volcanic and contact metamorphism, and there is also some risk of methane gas or hot water being encountered. The areas have two main formations – Chimu and Casma – split across the upper and lower portions of the hydro scheme.

The Chimu formation at the transfer tunnel and upper section of the headrace tunnel is a mix of quartzite, quartzitic sandstone, bituminous shale, coal in the Chimu Formation and volcanic breccia.

The mid-to-lower headrace area is in the area of the Casma Formation with andesitic rocks and some granodiorite, and the latter

for along the remainder of the alignment.

The rock in the powerhouse complex is grandiorite. Some may also be met in the tailrace excavation but the rock is mostly andesite and some hornfels.

Overburden varies significantly over the length of the headrace, from approximately 135m to more than 1,200m in the lower portion of the tunnel, up from the powerhouse and transformer caverns, which are themselves under about 750m of rock cover.

Tunnelling

Excavation is underway at a number of faces on the project – in the transfer tunnel, the upper and lower headrace, the powerhouse cavern and tailrace. The access tunnel to the powerhouse cavern passes through the transformer site and has been completed. The tunnels are being supported with shotcrete and bolts.

At the lower end of the scheme, more than a third of the tailrace has completed, tunnelling from the downstream end.

Coming in through the 953m-long main access tunnel, and a further 143m to cut through the transfer cavern space and gap to the powerhouse cavern, the contractor has excavated more than 5,600m³ for the crown (96m²) of the main hall. In addition, a number of bypass tunnels around the caverns have been constructed.

High in the catchment area, excavation of the transfer tunnel is being blasted from

the lower end while the first short section for the portal at the upper end has already been created.

Two adits with lengths of 152m and 893m respectively have been completed in the upper section of the headrace and early advances are underway in the main tunnel starting from both adits.

The 152m Checra HRT adit has allowed faces to be advanced upstream, towards the inlet end of the headrace, and downstream to complete just over a third of the planned drive for that section.

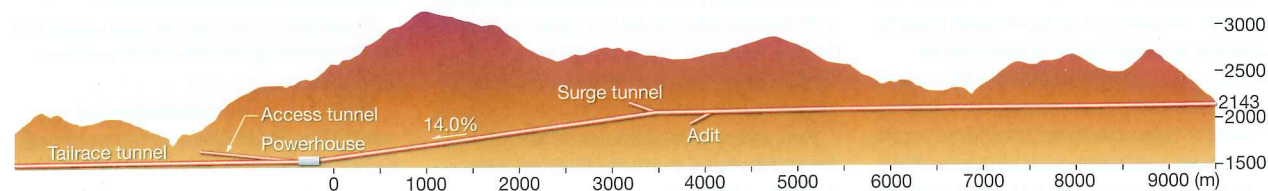
The 893m adit one has also allowed excavation to proceed in both directions, including reaching the site for the offshoot surge tunnel to enable its excavation to begin in earnest.

Equipment being used for the tunnelling work includes seven Sandvik DT 720 twin boom jumbos, and also from the manufacturer a DC 301 rubber-tyred bench drill. There are four Gia Haggloader HR 10 loaders and three ITC 312 excavator/loaders and five CAT 938H/950H wheel loaders.

On the underground works there are also four Terex TW 110 mobile excavators and a pair of CAT 330D crawler excavators, plus 10 Manitou MT 1030 telescopic handlers and 20 DUX/Paus DT 20 dumpers.

The main tunnel equipment is completed with a half dozen Semmco Alpha 20 shotcrete robots, 16 MB Actros 3336 rear tippers and 17 Dieci L 4700 truck mixers.

Below: Longitudinal section of works



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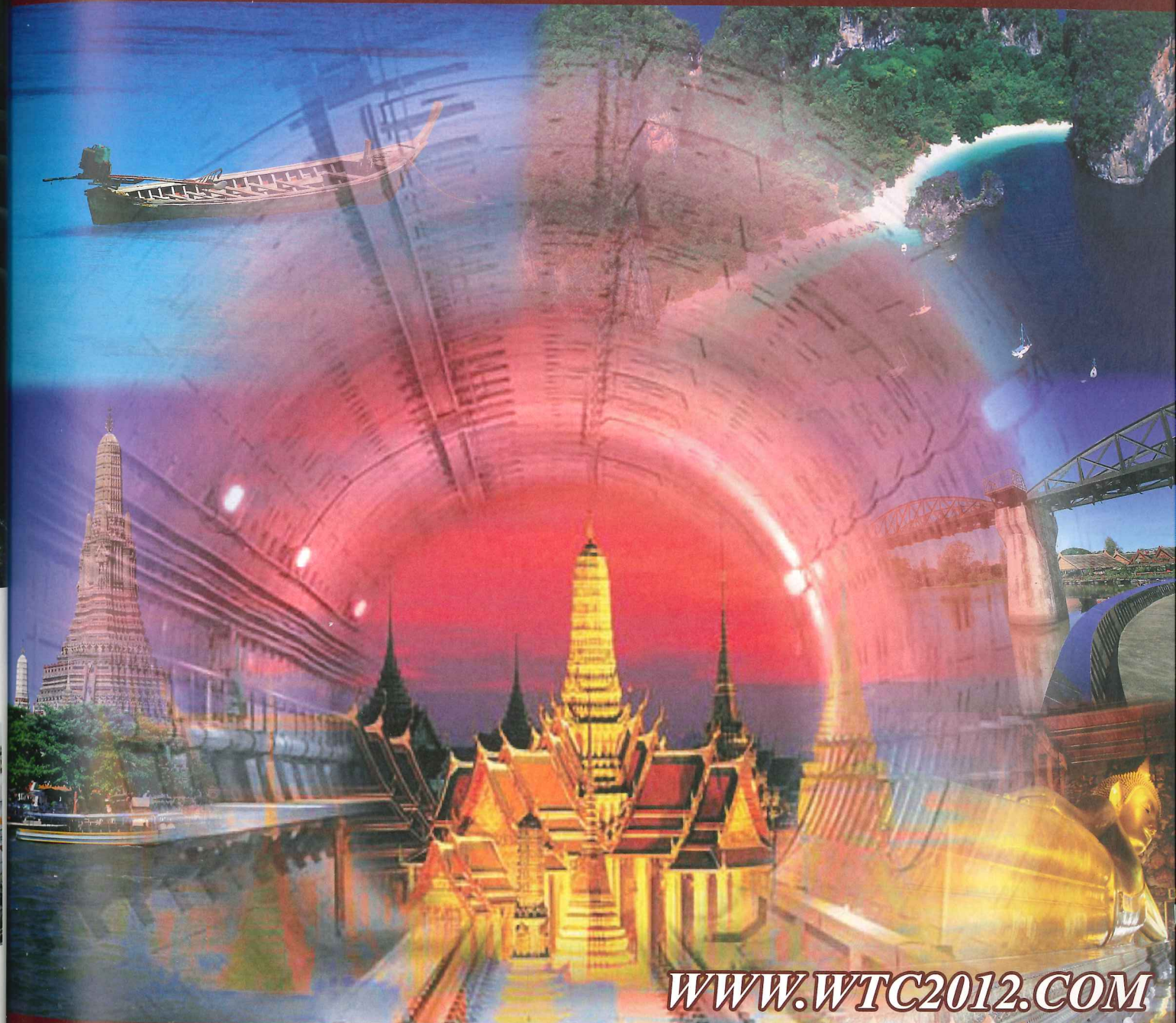
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Buenos Aires settlement control

The Arroyo Maldonado tunnel project in Buenos Aires, Argentina aims to prevent the floods that periodically inundate the surrounding area of the Rio de Plata river. Some 15km of tunnels are located in difficult urban areas with little overburden. Enrico Dal Negro, Alessandro Boscaro and Richard Schulkins of the Mapei Underground Technology Team explore the difficulties

A few years ago the government of Buenos Aires commissioned the Arroyo Maldonado tunnel project with the aim of reducing the inundations that periodically hit the Argentinean capital, causing incalculable damage to people and structures.

The project involves the construction of two 7.9m-diameter tunnels, with the function of catching and conveying rain water to Rio de Plata River. The client is Gobierno de la Ciudad de Buenos Aires, with Geodata as designer and Ghella as the contractor. Two Lovat EPBMs were used.

In September 2009 the first TBM was launched on the approximately 5km-long 'short tunnel' and finished it after about 350 working days. Construction on the 'long tunnel' started a few months after the first and was completed in December 2011.

Along the alignment the TBM mined through varying geological conditions with low overburdens, generally 15 to 30m with

particularly challenging passages less than 10m under existing structures including old hydraulic channels and buildings.

Table 1. Arroyo Maldonado project characteristics.

Tunnel length	~15km
Excavation diameter	7.9m
Lining type	Precast segments
Ring connections	Bolts
External ring diameter	6.9m
Internal ring diameter	6.55m
Segment length	1.5m
Segment thickness	350mm
Number of segments for ring	Six plus crown

Choice of a suitable ground conditioning system

The choice of the most appropriate products and parameters for the ground conditioning is of paramount importance to achieve satisfactory TBM performances.

In particular, the attention that had to be given to ground conditioning in the Arroyo Maldonado tunnels was even greater than in standard tunnelling projects, because of the continuous variations of geological profiles, as well as the low and sometimes very low overburdens.

Sometimes ground conditioning is described as a 'black art', however some parameters can be taken in consideration in order to rationalise it. In particular the following steps were observed for the Maldonado tunnels:

- Significant laboratory tests: a series of tests were carried out in the laboratories located at the Technical University in Turin, Italy with representative samples of the different types of soil to be excavated. This first step identified the most appropriate foaming agent and gave the contractor a first approximation of the ground conditioning parameters and consumptions. The laboratory tests gave indications that the product Polyfoamer FP (biodegradable foaming agent in combination with a lubricating polymer, produced by Mapei) was totally compatible with the types of soils to be excavated on the project.
- Optimisation of the ground conditioning system directly on the TBM: the parameters calculated in the laboratory were used as reference and modified with the aim to achieve the most appropriate solutions from technical and economic points of view.
- Adjustments of the ground conditioning parameters during the advance, focusing the attentions on geological variations.
- Continuous controls of the consistency of the muck extracted by the screw conveyor and of the TBM parameters, such as cutting wheel and screw torques, advance speed, and also working pressures in order to understand as early as possible eventual problems or difficulties in the EPB operations which can be solved (partially or totally) by changing the ground conditioning system.

During all four steps the cooperation between the contractor and the supplier was proficient and useful to solve the eventual problems encountered during the TBM operations.

A rational ground conditioning system used during the whole tunnel alignment and

Table 2. Monthly production of the TBM excavating the short tunnel.

Month	Number of rings excavated	Advance in metres
Oct 09	22	33
Nov 09	87	131
Dec 09	80	120
Jan 10	165	248
Feb 10	315	473
Mar 10	365	548
Apr 10	233	350
May 10	393	590
Jun 10	475	713
Jul 10	304	456
Aug 10	421	632
Sep 10	182	273
Average	254	380



the choice of appropriate foaming agents allowed the contractor to achieve satisfactory advance performances in both short and long tunnels.

The appropriate use of conditioning products allowed EPB control during the whole advance within the design ranges of minimum and maximum pressures, including the most challenging sections.

In the long tunnel excavated under the

Rio Subteraneo, overburden reduced to a minimum of just 6m. It was clear that in such conditions the EPB pressure must be controlled perfectly: the result was that no movements were registered.

A proper addition of foam gives the soil a consistency able to transmit pressures to the face and decrease its permeability significantly, and better controlling the water ingress inside the chamber. As a



Table 3. Monthly production of the TBM excavating the long tunnel.

Month	Number of rings excavated	Advance in metres
Feb 10	1	2
Mar 10	65	98
Apr 10	127	191
May 10	108	162
Jun 10	286	429
Jul 10	267	401
Aug 10	348	522
Sep 10	435	653
Oct 10	274	411
Nov 10	482	723
Dec 10	214	321
Jan 11	328	492
Feb 11	352	528
Mar 11	221	332
Apr 11	493	740
May 11	392	588
Jun 11	286	429
Jul 11	346	519
Aug 11	463	695
Sep 11	355	533
Oct 11	350	525
Nov 11	366	549
Average	298	447

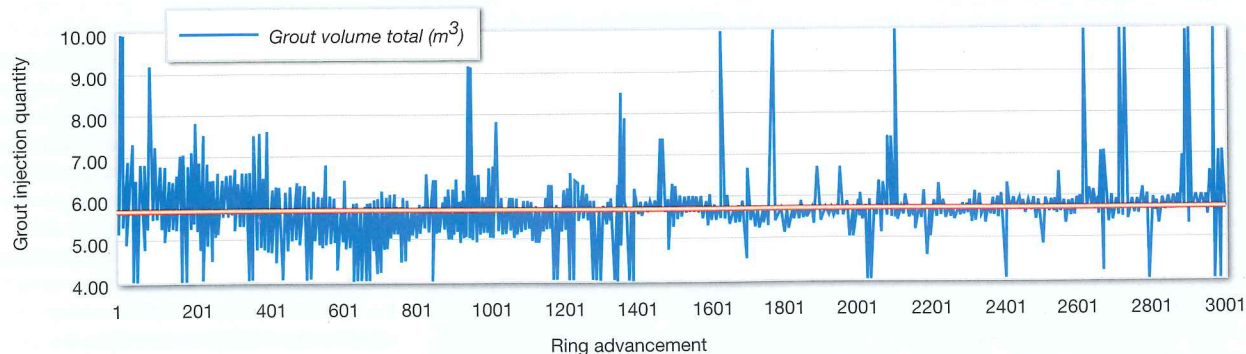
result, the surface settlements can be better controlled.

Two-component backfill grout injection for a complete filling of the annular void

The filling of the annulus void created during the shield advance was carried out in Maldonado with a two-component grout

mixture made of:

- A very fluid and stable cementitious grout, with long workability properties due to the addition of the retarding agent Mapequick CBS System One, produced by Mapei.
- An accelerator admixture, the Mapequick CBS System Two, added to the cementitious grout and able to react,



Above: Figure 1, the conveyor carries the conditioned soil from the TBM face; **Below:** Figure 2, a graph to indicate the volume of grout injected as the tunnel advances by rings

resulting in a thixotropic and non-washable gel.

Several tests carried out, firstly in the laboratory (using the raw materials received from Buenos Aires) and later at the job-site, were useful in finding the most appropriate mix-design according to all the specific requests coming from the project, in terms of pumpability, volumetric stability, jellification and mechanical strength development.

Two factors were considered by the contractor during the injection to control the real complete filling:

- The volume: knowing the theoretical empty volume left by the shield behind the segments, a slightly higher amount of grout must be injected.
- The pressure: the injection was carried out during the advance with average pressures slightly higher than the EPB

ones, until achieving a maximum pressure at the end of every advance.

These two parameters were continuously checked and allowed the contractor to properly fill the annulus space in both short and long tunnels.

Graphs showing the grout volume injected per ring allowed the contractor to control and confirm the complete filling of the empty spaces behind the tunnel segments. Figure 2 (below, left) clearly shows a homogeneous grout volume injected with an average of approximately 6.1m³ per ring.

The theoretical volume to be injected per ring is 5.7m³.

By using a proper mix-design and specifically designed equipment, the risk of clogging the pipes was minimised, ensuring a constant and continuous injection of the mix. If the injection lines are often clogged, the injection cannot be constant and it is more probable that empty spaces will be left behind the lining.

The durability of the two-component backfill grout is guaranteed in the natural conditions of humidity present in the underground excavations.

In the short tunnel it was possible to directly observe the backfill grouting material due to the removal of superficial ground down to the tunnel depth a few months after the TBM passage. As shown in figure 3 (right), the two-component material was found in perfect conditions, hardened and perfectly filling the space between the tunnel lining and the surrounding ground.

Conclusions

Ground conditioning and backfill grouting carried out in the Arroyo Maldonado project were both described in this paper. The operations are of paramount importance to minimise the surface settlements, particularly under difficult conditions such as in Buenos Aires: very urbanised areas, reduced overburden and the presence of underground water with an average pressure of two bars.

Appropriate use of the foaming agent Polyfoamer FP allowed for correct ground conditioning, improving the pressure transmission through the soil mass, which lead to better face stability and guaranteeing satisfactory TBM advances and performance.

The two-component backfill grouting injection allowed a complete and immediate fill of the annular void behind the tunnel lining, minimising volume loss around the tunnel and therefore minimising associated settlement. ■



Table 4. Surface settlements along the short tunnel

Distance (m)	Last data	Settlement (mm)
48	16/12/09	-2.6
87.5	04/01/10	-0.7
243.89	06/02/10	-1
682.8	16/04/10	-2
866.82	13/04/10	0.6
904.7	13/04/10	-0.7
1,549.34	16/04/10	-0.1
1,929.72	22/12/11	-1.6
1,934.09	22/12/11	-1
1,954.09	28/06/10	0
2,146	01/12/11	-1.9
4,459.6	12/12/11	-2.1



Above: Figure 3, a clear view of the backfill used to fill the annular space left between the ground and the tunnel lining as the TBM advances

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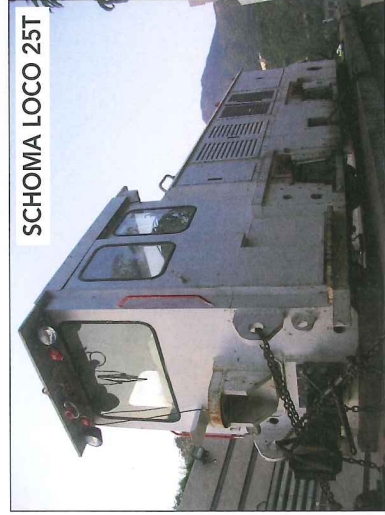
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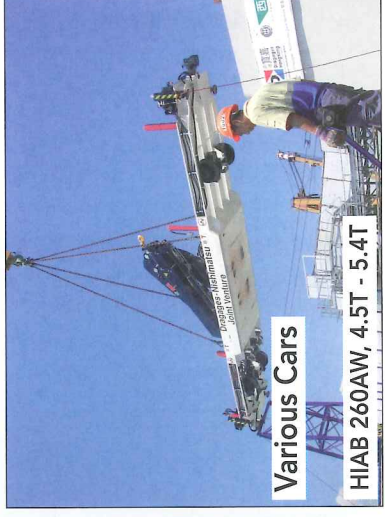
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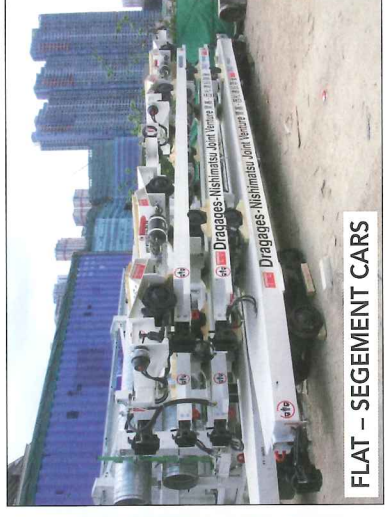
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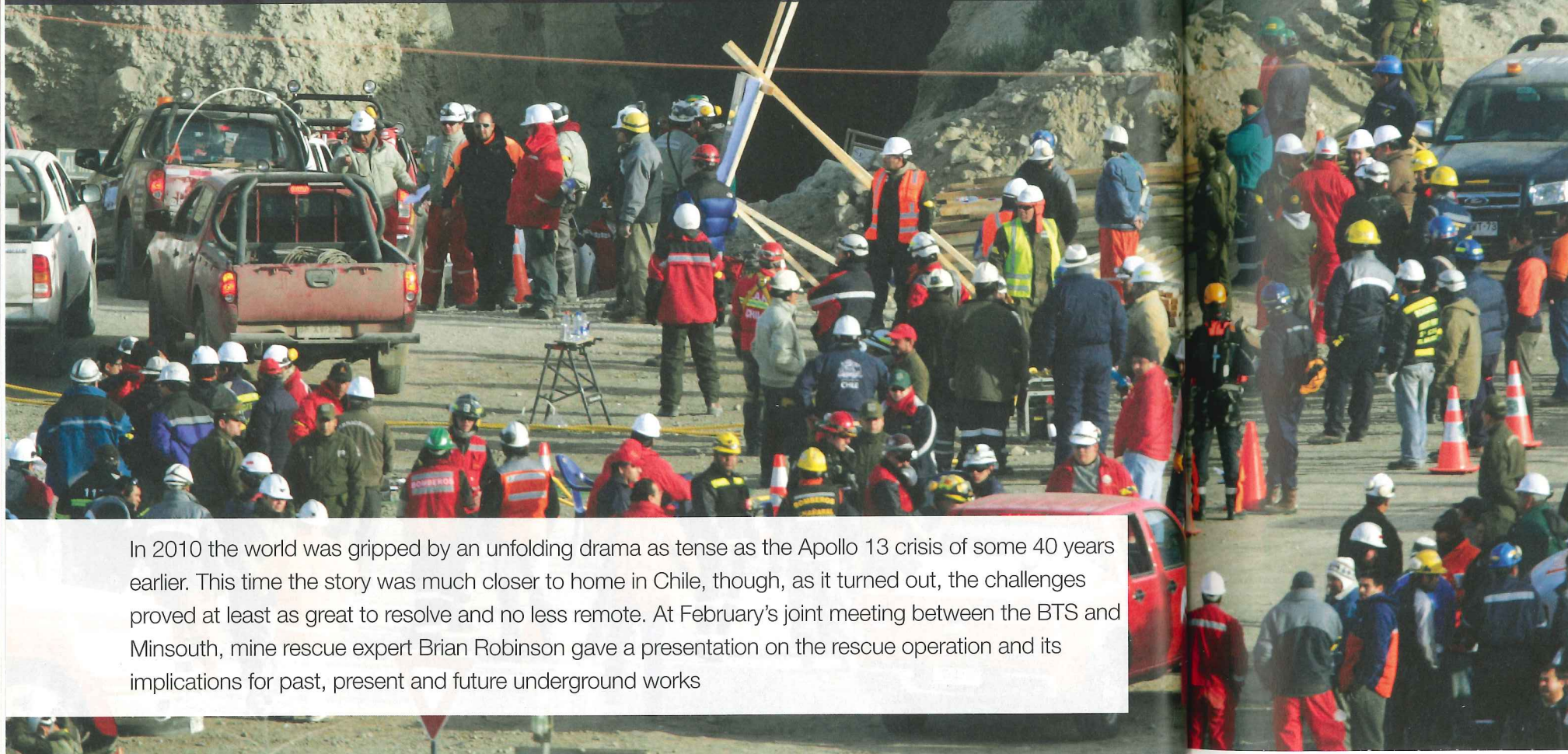
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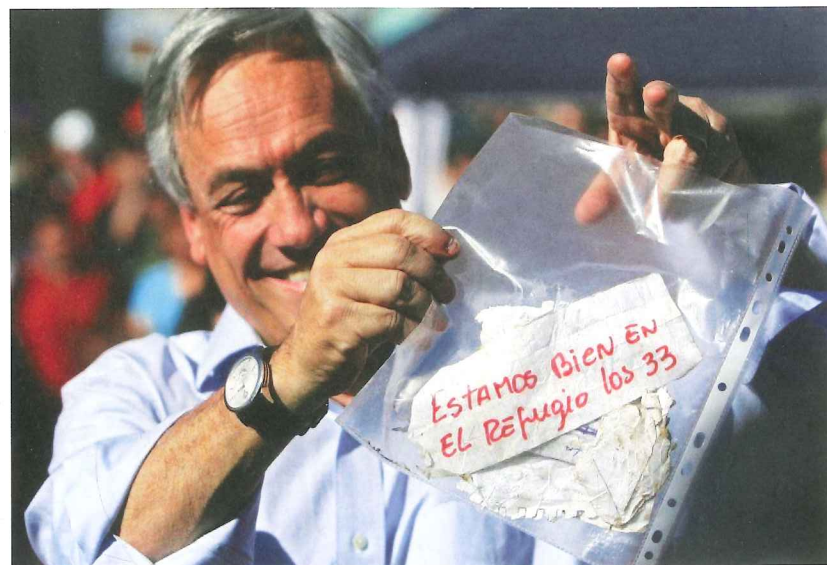
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Chile mine rescue



In 2010 the world was gripped by an unfolding drama as tense as the Apollo 13 crisis of some 40 years earlier. This time the story was much closer to home in Chile, though, as it turned out, the challenges proved at least as great to resolve and no less remote. At February's joint meeting between the BTS and Minsouth, mine rescue expert Brian Robinson gave a presentation on the rescue operation and its implications for past, present and future underground works



The Atacama region in South America is a very large mining area producing great volumes of copper and gold, which together are the largest GDP providers in Chile. Labour comes from not only Chile but also the neighbouring countries. The miners are drawn to the higher paying locations which are also the most dangerous. These range from semi-illegal operations employing just a handful of people to the larger mines with 600-700 people.

Yet there are only three government mine inspectors in the country. Codelco is one of the largest employers that run very safe operations underground but unfortunately

Left: Chilean President Sebastián Piñera holds the note left on the drill bit by the trapped miners

this culture does not occur in all other mine operations.

San Jose

The scene of the 2010 accident was the San Jose mine in northern Chile. It started life in 1889 with the existing headgear over the access shaft having been in place since around 1910. The ropes for this do not go down the full depth of the mine, so were not good for the rescue from the deep levels. The access shaft was further laid to waste by the removal and sale of many of its ladders in a bid for extra revenue.

Mining at San Jose has mostly been continuous since it opened except for a short closure in 2009 due to a dispute between the miners and owners over the safety of the mine. It still made a profit of USD 20M in 2009. There had been eight



Far Left: The mine entrance
Left: Figure 1, San Jose mine is some 600km north of Santiago and 90km from the coast, making logistics difficult

deaths in twelve years with the last in 2007 but this made little impact on the safety of the mine.

The mine is about 600km north of Santiago and 90km from the coast though being a mountainous region, the transport of equipment to the mine takes about five days from the coast.

Collapse

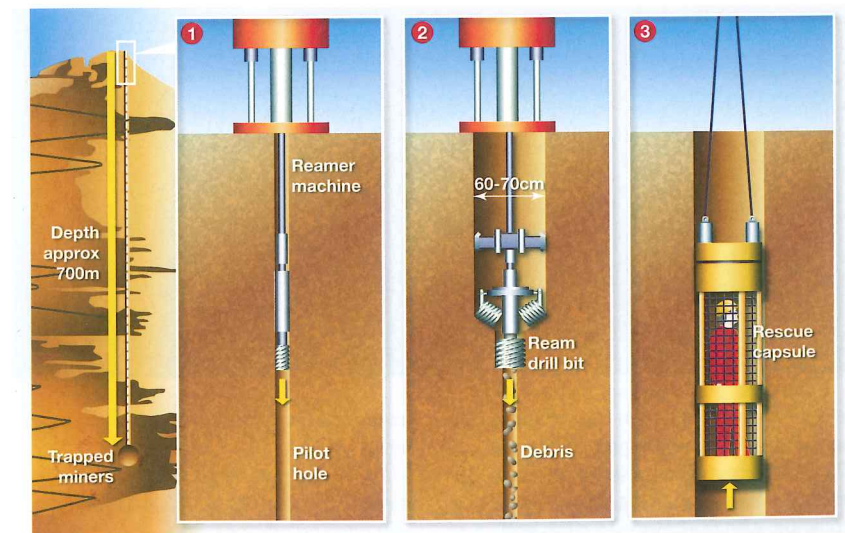
On the afternoon of 5 August, 2010, a section of the mine from 350m deep to 630m deep completely caved in. This was day 0 for 33 miners in the deepest levels of the mine. This collapse surpassed any mine collapse before it and shocked the international mining community.

The 8.5km long ramp used to access the mine face had completely failed. It is believed that overmining of the ramp structure itself led to the collapse.

In an effort to make the mine more productive, the operator had removed the ramps support structure for any gold or copper left in it.

Immediately following the collapse all communication was lost with the trapped miners and it was impossible to know if anyone had survived.

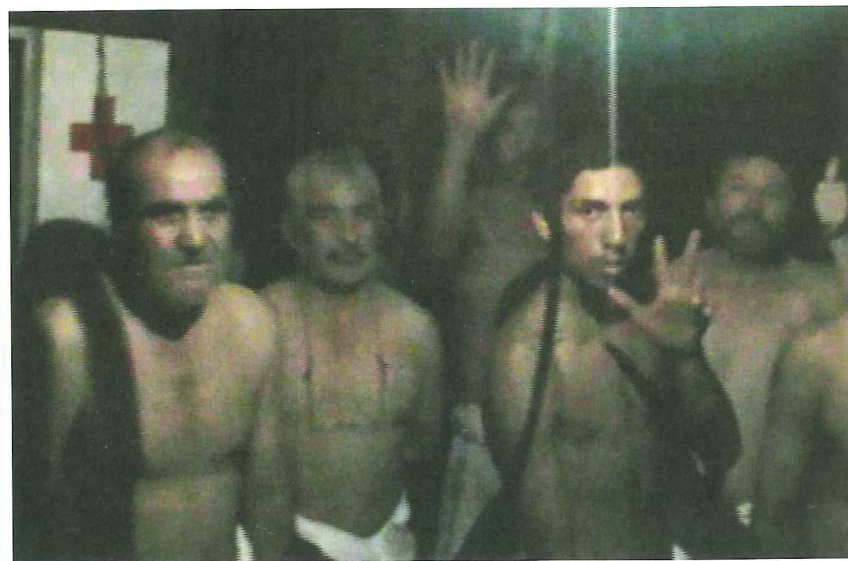
Rescue workers and the Chilean Government officials were quickly on the scene but with no maps of the mine at all it was difficult to start assessing the damage. The maps now available (see right, overleaf) were drawn after the event. The extent of the collapse was also unknown initially though it was thought that engineers could



Above: The drilling, reaming and removal process for the mine rescue



Above: Miners arrive at the surface after being extracted by Phoenix Two
Left: A still from CCTV footage from within the mine after rescue workers make contact



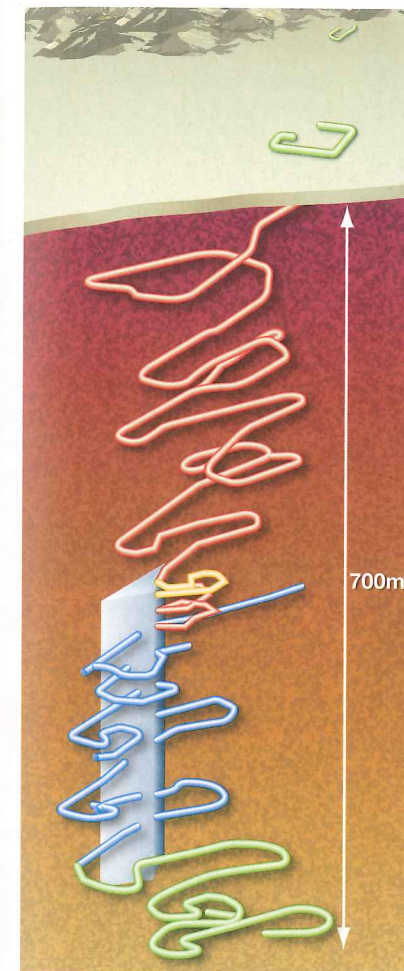
re-mine the ramp through the collapsed section to reach the trapped personnel. This started but stopped soon after it was realised it was futile and possibly fatal to continue, with the collapsed ramp and

access shafts providing further dangers to rescue teams.

Other attempts to access the lower levels also failed due to blocked accesses and ongoing collapses.

With remaining ruled out, Codelco sent 18 rigs to bore pilot holes to attempt to locate the trapped miners. Without any plans of the mine it was down to the mine's foreman to guide the boreholes. Standing at the mine entrance the foreman paced out his journey down the ramp in his mind and suggested rig positions. Drilling operations were fraught with difficulties as drill bits encountered hard ground and existing mine plant and equipment.

As drilling continued it became clear that the mine was completely choked from 350 to 505m depth and at this point many were considering giving up. From a consensus on conversations between the mine rescue teams, until the full mine depth had been reached, there was still a possibility of finding live people. The Chilean government also supported this approach.



Left: Figure 2, a plan of the mine showing the section that collapsed

that all 33 miners were alive at a refuge chamber (see photo, page 46).

It was decided to continue drilling with three rigs as a contingency in case any of the drill holes collapsed. The first hole was used as a supply route for water, food, messages and medical equipment.

On day 17, a camera was put down that allowed the first view of the miners. Obviously no medical staff could reach the miners but proper food and supplies could be delivered. Experts from NASA advised that no solid food was to be delivered initially. Only high energy drinks and liquids to rehydrate the miners, much to their consternation, though NASA also supplied a rolled up TV screen with DVDS for the miners to watch. The supply hole allowed charged light to be sent down which would last for 24 hours and was continually resupplied. Later on, ventilation was supplied with cool air along with cables for video conferencing.

The miners' only lighting had been their cap lamps which ran out early on. A Toyota SUV was then used with its engine running to keep the headlights running. Once that had run out, water from the radiator was used for drinking water. Cannibalism had also been discussed.

Equipment and personnel from around the world were used to aid in the rescue attempt but once a large bore had reached the miners the other two rigs were shut down before they reached their full depth. Drill bits from Belfast were supplied.

Raise boring technology was used to enlarge the hole but the problem here was that normally you would have the large reamer in a single piece underground. For the rescue the reamer had to be lowered down and re-assembled. The 33 miners

Contact

Two days later on day 14 the drill had reached 670m depth and reached a void where the drill was pulled back so a CCTV camera could be lowered down. Upon pulling the drill out, the rescuers were shocked to see on the end of the drill bit a poly-pocket with a note inside explaining

Questions from the floor

Gavin Bowyer of Minsouth asked what size the capsule was.

Robinson explained that 18 stone (115kg) was the limit and this was why the weight loss was important.

Mike McConnell of Balfour Beatty asked what guidance techniques were used for the pilot hole.

Robinson said eight holes were sunk but in addition to this expert crews were used to ensure the right area was targeted. The furthest deviation was only 2m over a 630m depth. The hard ground made it easier to maintain the direction.

Alan Baxter of Minsouth asked if the miners suffered from any psychological issues from being trapped for so long.

Robinson said the NASA team did send some information on this but being miners, they were very resistant to it. NASA did produce a diet that would help them cope mentally before the final rescue.

Neville Harrison (consultant) asked how did the miners avoid being choked by the fumes from the Toyota being run underground.

Robinson said this remains unknown as all ventilation was shut down. The miners did run the vehicle intermittently to avoid running out of fuel which may have allowed dissipation of fumes.

Rapporteur: Andrew Hindmarch

were engaged in removing excavated material. The foreman arranged three shifts and it proved to be a huge morale booster.

Extraction

On day 66, Phoenix Two, the rescue capsule was able to be tested and lowered down. The hole also passed through two roadways so it had to be a set length so it did not deviate off the required angle. Communications were maintained throughout the extraction process.

Two paramedics were sent down to check the miners over before they were allowed out.

On day 67 the miners were all successfully rescued with no major injuries.

Some of the miners did suffer from medical problems after the rescue including dental problems due to the acidic water, with some requiring surgery due its effects. Silicosis problems were also present though some miners had this already.

The cost of the rescue operation has not been finalised yet but estimated at between USD 10M and USD 20M. There were up to 800 people on the surface helping with the rescue attempt.

The assets of the mine were seized by the government five days after the mine rescue operation to help pay for the costs with the rest provided by Codelco and the Chilean government.

Future planning

In planning for future events, the supplies the miners had to rely on were looked at. Before the miners were reached, they only had the food with them and emergency food for two days.

The foreman had begun a rationing process with two spoonfuls of tuna, one biscuit, and a little milk every 48 hours until the supplies were exhausted on day 16. The miners experienced an average weight loss of eight kilograms each.

The UK did put together a contingency plan of heavy mining equipment which was ready to be flown out if necessary.

Lesson could be considered for major tunnelling projects such as Crossrail. With a full face TBM and lining behind, the chance of a similar incident occurring is very low, however a flooding event in South Wales in September 2011 led to the deaths of several miners.

If boreholes were to be sunk for rescue attempts in a major city, the existing infrastructure may well preclude large areas from being used for drilling attempts. For mining operations a register of personnel and equipment has been assembled if a similar rescue attempt is required. ■



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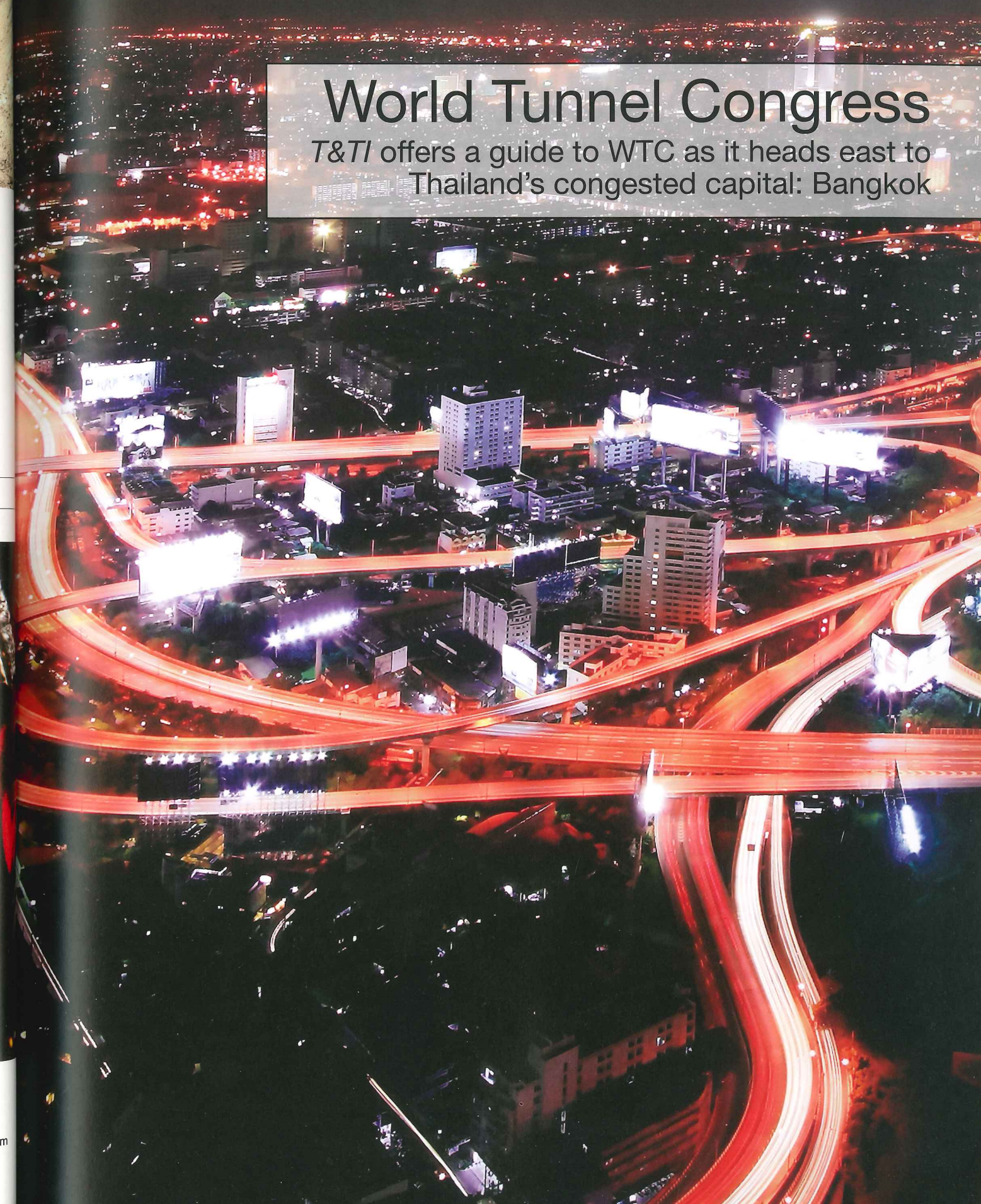
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Tunnellers head to Thailand

Bangkok is this year host to the World Tunnel Congress, *T&T* looks at what is in store for the event and what you can enjoy while you are there

The tunnelling community are descending on Bangkok, Thailand, this month for the 2012 World Tunnel Congress organised by the International Tunnelling Association. The theme for 2012 is "tunnelling and underground space for a global society" which will explore some traditional avenues such as innovations in mechanised tunnelling, but will also venture into urban tunnelling, tunnelling near sensitive

buildings and coping with natural disasters. President of the Engineering Institute of Thailand Suwat Chaopricha says, "The Asia region including Thailand has witnessed the tremendous development of infrastructure projects including the construction of mega underground structures. Recent developments have been spurred by the increasing demand for various types of tunnels and underground structures particularly in the congested

urban environment."

As a rapidly growing city tackling all of the pressures of maintaining infrastructure development and as one of the world's most popular tourist destinations, Bangkok offers a great opportunity for the global tunnelling community to measure the South East Asia market and see a few sights while there. In the following pages *T&T* gives a quick guide to the event and the locale.

Expanding Horizons

Underground

MEYCO

Vital statistics

Currency: USD 1 = THB 30.8 (Thailand Baht)

Electricity: Wall sockets are 220V, 50Hz. Plugs with two flat pins are common.

Taxis: The meter should start at approximately THB 35, a short trip in central Bangkok should not rise much above THB 100. Taxiprices.com advises visitors to beware of scams, and never accept fixed prices but ask for the meter. English language may be a problem.

Buses: Fare up to THB 16

Eating: A quality meal for two costs around THB 300-500. "Undoubtedly one of the most popular places to eat in Bangkok is alfresco-style like the locals do – on the street. Fold-up tables and little plastic chairs might not be your idea of elegant dining, but certainly makes for a memorable experience.

"Thai food can be easily found, from very spicy northeastern favourites like 'som tum' (spicy papaya salad), the national dish 'tom yum koong' (a herbal and spicy prawn soup), wonderful fresh seafood and yellow curries with a southern influence. The more adventurous you are, like trying the fried bugs some street vendors sell, the more you'll have to boast about then you arrive back home." – gothailand.com

Beer (330ml): THB 60-150

Tipping: There is no mandatory tipping policy in Thailand, but offence won't be caused for rewarding exceptional service or a tough request carried out. The basic wage in Thailand is not high, so tips are gratefully received.

Round your fare up in a taxi, but no additional tip.

Mid to high-range restaurants often include a 10 per cent service charge, in lower range it is customary to leave any coins given as change.

Tips in hotels not expected, but THB

20-50 for porters or cleaners (per day for the latter) are considered appropriate.

For professional services, e.g. a massage or haircut, a tip of THB 20-100 is appropriate. Tour guides and drivers giving a one-to-one service can warrant up to a THB 500 tip. – Tripadvisor.co.uk

Etiquette guide: As a general rule, Thailand is a modest country, so overt displays of affection, emotion or skin can be awkward. Feet are also considered dirty/rude/insulting. But there are other specific pieces of advice:

There are special rules for being disrespectful to the Thai Royal Family – even stamping on a coin that is rolling away can be insulting (remember the foot rule).

Stand during the anthem, e.g. in the cinema before a film.

Hail a taxi with your arm out, hand horizontal with palm facing downwards. Whistling or clicking to attract someone's attention is also rude.

In temples, remove shoes. Women should wear long trousers or skirts with covered knees, and shoulders. If sitting, keep legs crossed or tucked.

Hygiene, odour and appearance are important to avoid offence. Thai people are very conscious of cleanliness.

Touching someone's head, unless a very good friend, is offensive.

The Thai greeting 'the Wai' sounds like the English 'why'. Unless you are an expert on the correct tone and hand positions, do not attempt it. Smile widely and slightly nod your head. Never Wai a service person or a child.

If you are female, never touch a monk, or even pass something directly to one.

Some rural Thai people believe photographs can capture their souls

Six things to do

Attractions that are hard to find elsewhere:

- 1) Go for a Tuk-tuk ride. A dangerous, noisy, overpriced milk float style taxi that is amazing fun.
- 2) Shop at Chatuchak Market. A dirty, semi-legal market where you can buy most animals, as well as clothes, souvenirs and food. Don't buy the animals.
- 3) Get a massage. There are many types: oil, soap, foot... if you are delicate, don't choose the Thai massage variant.
- 4) Street food. Cheap, fast-selling and high temperatures of cooking make it hygienic. Stall specialisation makes it good.
- 5) Watch a Muay Thai fight. A particularly aggressive and fast form of kickboxing – go for the cheap seats in a non-tourist fight – the gambling and bloodlust are the real show.
- 6) Eat insects. Locusts or grubs.



Tuk-tuk

Where to stay

Special arrangements have been made with these hotels for discount rates. All hotels have free Wi-Fi. Prices inclusive of service charges and tax, breakfast varies.

Sheraton Grand Sukumvit

Contact: vasin.chaiyawan@luxurycollection.com
Price start from 5,500
8 minutes walk to BTS station / 1 BTS and 1 MRT station to venue

The Westin Grande Sukhumvit

Contact: pimpawan.khasuwan@westin.com
Price start from 5,000
8 minutes walk to BTS station / 1 BTS and 1 MRT station to venue

JW Marriott Bangkok

Contact: somchai.c@marriotthotels.com
Price start from 4,600
Round trip shuttle bus transfer to /from Hotel-QSNCC during event date
10 minutes walk to MRT station / 2 BTS station to venue

Dusit Thani

Contact: infowtc2012@dusit.com
Price Start from 4,555
MRT is directly outside of the hotel's doorstep

Grand Millennium Sukhumvit

Contact: WTC2012@grandmillenniumskv.com
Price start from 4,900
Round trip shuttle bus transfer to /from Hotel-QSNCC during event date
5 minutes walk to MRT station / 1 MRT station to venue

Pathumwan Princess

Contact: reservationwtc2012@pprincess.com
Price Start from 3,500
Round trip shuttle bus transfer to /from Hotel-QSNCC during event date
5 minutes walk to BTS station 4 stations to MRT station / 1 station MRT to venue

Furama Xclusive Asoke Sukhumvit

Price start from 3,000
Complimentary daily MRT Ticket pass per day. MRT Station is just in front of hotel

Imperial Queen's Park Hotel

Price start from 3,200
Round trip shuttle bus transfer to /from Hotel-QSNCC during event date
5 minutes walk to BTS station / 1 BTS and 1 MRT station to venue

Grand Mercure Fortune

Contact: sales4@grandmercurerfortunebkk.com
Price Start from 2,350
MRT station is just in front of hotel / 2 MRT stations to venue

Imm fusion

Price Start from 1,500
Complimentary daily BTS Ticket pass per day. BTS Station is just in front of hotel

Golf tours

Thailand has some of the most beautiful and challenging courses in Asia. Enjoy one 18-hole round of golf at your choice of world-class courses in the Bangkok metropolitan area. Each One-Day Golf Tour includes a reserved tee-off time, Caddy & green fees with the use of golf cart, and transfers from hotels to golf course and return. Rates do not include golf equipments, traditional tip for caddy, personal expense as drinks. Booking less than 5 players may be joined with other players.

Muang Kaew Golf Course.

This 18-hole course is conveniently located close to Bangkok with only a 20-minute drive from the city bustle. Its verdant greens and tree-lined fairways give the impression that you are in the middle of the countryside. A full range of complementary facilities, including a swimming pool and massage room, is also available.

Prices per person (min. 2 pax):

- Baht 5,300.- for weekdays
- Baht 6,200.- for weekends and holidays

Thana City Golf Course

Located just 40 minutes from the city, Thana City Golf & Sports Club is the only Greg Norman designed golf course in Thailand. The 6,966-yard par 72 course is set in beautifully landscaped surroundings and features fast greens, strategically placed bunkers as well as natural lakes and streams. Facilities include the golf course and clubhouse, a comprehensive sports facility, a world class driving range, practice facilities and a golf academy that is recognized throughout the region as one of Thailand's best golf training centers.

Prices per person (min. 2 pax):

- Baht 5,400.- for weekdays

• Baht 6,700.- for weekends and holidays

Lam Luk Ka Country Club

A short drive from the city center to the northeast of Bangkok, Lam Luk Ka sets the stage for a golf experience not easily forgotten. Both courses meander through Bangkok's wetlands, where over 10,000 trees and waterways provide homes to over 100 species of birds and wildlife.

Prices per person (min. 2 pax):

- Baht 5,300.- for weekdays
- Baht 6,100.- for weekends and holidays after 11.10am only

Spousal programme

The following tour programmes will be arranged for accompanying persons at no additional cost.

Highlights of Bangkok

Time Schedule: 22 May 2011

Meal: Lunch included

Tour Description: You will travel by coach to visit vibrant Chinatown, Bangkok's commercial center for more than 200 years, the Royal Palace Grounds and the spectacular Wat Phra Keo with its Emerald Buddha, Chaina town, Park-Klong-Talad to visit the flower market, Wat Po, or the Temple of the Reclining Buddha, the oldest temple in Bangkok.

Ayutthaya - A UNESCO World Heritage Site

Time Schedule: 23 May 2011

Meal: Lunch included

Tour Description: Step back into the days when Thailand was Siam as you visit the unforgettable beauty of Ayutthaya - a UNESCO World Heritage Site.



Congress socials

Welcome Reception

Date : Sunday, 20 May 2012

Time: 19:00-21:00 hrs

Venue: Plenary Hall 3, QSNCC

Opening Ceremony

Date: Monday, 21 May 2012

Time: 9:00 – 9:30 hrs.

Venue: Plenary Hall 1, QSNCC

Closing Ceremony

Date: Wednesday, 23 May 2012

Time: 16:30 – 17:00 hrs.

Venue: Ballroom /QSNCC

Banquet

Date: Wednesday, 23 May 2012

Time: 19:00-21:30 hrs

Venue: Napalai Ballroom / Dusit Thani Bangkok



Street food



- Hotels:**
1. Imperial Queen's Park
 2. Royal Benja Bangkok
 3. JW Marriott Bangkok
 4. Ambassador Hotel
 5. Zenith Hotel
 6. Conrad Bangkok
 7. Plaza Athenee Bangkok
 8. Swissotel Nai Lert Park
 9. Holiday Inn
 10. Intercontinental Bangkok
 11. The Arnoma Hotel Bangkok
 12. Grand Hyatt Erawan Bangkok
 13. Four Seasons Hotel Bangkok
 14. Novotel Bangkok Hotel
 15. Dusit Thani

Congress tours

Thailand offers a fascinating variety of options for pre- and post-Congress tours. These include:

- The nearby beach resorts of Pattaya and Hua Hin.
- Island getaways such as Samui, Phuket and Chang. Beach resorts on the Andaman coast are also very popular.
- In contrast to these sun-drenched beaches, there is the cool North, including Chiang Mai, Chiang Rai and the forested Mae Hong Son.
- The lower North has the original capital of ancient Siam at Sukhothai as well as Srisatchanalai and Kampanghet which are also historical sites.
- Northeastern Thailand is the gateway to the Greater Mekong Sub Region and also the location of many historical sites.

Half Day Grand Palace & Emerald Buddha Temple

Number of days for package: Daily, AM. / PM.

Rate per person: Baht 1,100 (minimum charge 4 persons)

Meal: Not included

Tour Description: Visit the Royal Palace Grounds, the spectacular Wat Phra Keo with its Emerald Buddha, Golden Chedi, Pantheon of Kings and Towers of Nine Planets

Half Day Bangkok Canals

Number of days for package: Daily, AM. / PM.

Rate per person: Baht 1,390 (minimum charge 4 persons)

Meal: Not included

Tour Description: Visit the Chao Phya River and canals. Stop at Wat Arun, the spectacular Temple of Dawn.

Half Day City & Temples

Number of days for package: Daily, AM. / PM.

Rate per person: Baht 800 (minimum charge 4 persons)

Meal: Not included

Tour Description: A tour of the capital featuring three enchanting temples: Wat Benchamabopit, Wat Po and Wat Trimit.

Half Day Elephants Theme Show at Samphran

Number of days for package: Daily, AM. / PM.

Rate per person: Baht 1,140 (minimum charge 4 persons)

Meal: Not included

Tour Description: Relive the excitement of Thai history when kings and princes fought mighty wars on elephant back.

Fully Floating Market & Rose Garden

Number of days for package: Daily, AM. / PM.

Rate per person: Baht 2,580 (minimum charge 4 persons)

Meal: Lunch included

Tour Description: Visit the bustling floating market at Damnersaduak with a stop at Nakorn Pathom to see the tallest pagoda in the world. Visit the Rose Garden for lunch. Next, enjoy the colorful Thai Village show, Buddhist ordination, sword fighting, elephants at work, folk dances and the traditional Thai wedding ceremony.

Registration details

Registration Fees (THB)	Early Bird Rate Until 10 March 2012	Standard Rate Until 10 May 2012	On-Site Rate After 10 May 2012	Package Included
Full Participants	30,000	33,000	36,000	<ul style="list-style-type: none"> • 3-day Congress including lunch and refreshments • Abstract book & Proceeding CD • Welcome Reception • Technical Visit (4 options)
Developing Country Check	15,000	16,500	18,000	
Student		10,000		<ul style="list-style-type: none"> • 3-day Congress including lunch and refreshments • Abstract Book and Proceeding CD • Welcome Reception • Technical Visit (4 options)
Accompanying Person		8,000		<ul style="list-style-type: none"> • Welcome Reception • 2 Tour Programmes
One Day Only (Including Open Session Tuesday 22 May 2012)		12,000		<ul style="list-style-type: none"> • Technical Programme • Materials for 22 May 2012 • Lunch
Congress Banquet, Wednesday 23 May 2012		1,000		<ul style="list-style-type: none"> • At Dusit Thani Hotel • Seat Reservation Fee is compulsory • Limited to 600 seats, as first come, first serve
ITA-CET Training Course		Click Here to Register		<ul style="list-style-type: none"> • Direct registration with ITA-CET Foundation

Who's on show

AECOM

AECOM is a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental, energy, water and government. With approximately 45,000 employees around the world, AECOM is a leader in all of the key markets that it serves. AECOM provides a blend of global reach, local knowledge, innovation and technical excellence in delivering solutions that create, enhance and sustain the world's built, natural and social environments. A Fortune 500 company, AECOM serves clients in more than 130 countries and has annual revenue in excess of USD 8.0 billion.

AFTESD5,

M1, M2

AFTES Association

O1

AFTES Plant Equipment Branch

N1, N2

Amberg & TTI Engineering

S4

Atlas Copco Rock Drills AB

V1

Babendererde Engineers GmbH

O4

BASF Construction Chemicals Europe AG

D1, D2

BEKAERT

C3

Brokk AB

O3

Caterpillar Tunneling Canada Corporation

A3, A4, A5

Caterpillar Tunneling offers a full line of tunneling equipment. TBMs from 2m in diameter to over 12m. Our machines are backed by world-class product support from launch to breakthrough. Cat TBMs help our clients succeed by delivering high quality solutions with reliable durable products which are built to be rebuilt. Custom built to suit your every project need. Our target is your Breakthrough!

CBE Group

D4

CH Karnchang Public Company Limited

R1, R2, R3

CIFA SpA

I3, I4

CIFA will be launching its new CST 8.20 (CIFA Telescopic Shotcrete) unit, designed specifically for use in small diameter tunnels. Robust and at the same time versatile and extremely precise on nozzle placement, it has a vertical reach of 10m. The boom has an horizontal slewing ring that allows the operator to follow the entire profile of the tunnel, at every height, with only one joystick movement on the proportional radio remote control.

Cooperativa Moratori e Cementisti Ravenna

H2, H3

Daetwyler Switzerland Inc.

T2

Denki Kagaku Kogyo

R4, R5

DMT GmbH & Co.KG

S1DSI Holding GMBH

B3, B4, B5

Durham Geo Slope Indicator

S2

Elasto Plastic Concrete (Asia) Pte.Ltd.

K2

FiReP Rebar AG

P1

Geodata Group

C4

Geodata

C5

Geokon

Q2

Founded in 1979, Geokon, Incorporated designs and manufactures a full range of high-quality geotechnical instrumentation suitable for monitoring the safety and stability of civil engineering structures including tunnels, mines, embankments, foundations, pipelines, piles, dams, and storage facilities. Tunnel-specific instruments include NATM-style concrete pressure cells, convergence meters, multiple-point extensometers, instrumented rockbolts, and tape extensometers. Recent additions include wireless multiplexers and inclinometer systems utilizing Bluetooth® technology.

GeTec GmbH

T3

Giertsen Tunnel AS

N4

Giken Seisakusho Asia Pte Ltd.

Q3, Q4



Who's on show

Gonar-System International	T1
HERCO Kühltechnik GmbH	G4
Herrenknecht AG	F1, F2, F3
InnoTrans 2012 - Messe Berlin GmbH	U5
ITALIAN-THAI DEVELOPMENT PLC.	V3, V4, V5
Maccaferri Industrial Group	P2, P3, P4
Mapei S.P.A.	E1, E2, E3
Matrics Consult Ltd	K1
MineARC Systems	V2
Mining Equipment Ltd.	F4
NFM Technologies	E4, E5
Normet International Ltd.	C1, C2
Norwegian Tunnelling Society	L4, M4
Power Curbers INC	F5
Powerking Co.,Ltd.	O2
Promat International (Asia Pacific) Ltd.	Q1

Promat are global leaders in fire protection of tunnels, providing fire protection solutions to many of the world's biggest tunnel projects. Promat provide specifiers and tunnel owner/operators with superior value by offering the widest range of effective solutions, including the Cafo FENDOLITE® MII spray system and Promat PROMATECT® board systems.

Promat fire protection solutions are equally effective as part of an existing tunnel refurbishment as well as new construction projects.

Putzmeister	B1, B2
Rehau Pte Ltd.	D3
Right Tunnelling Co., Ltd	J4
Robbins Company	J1, J2

The Robbins Company provides successful solutions to the world's most challenging tunnelling projects. In 2012 the leading manufacturer of underground construction equipment has further proven its Onsite First Time Assembly (OFTA) method, launching hard rock and EPB TBMs four to five months earlier than comparable shop assemblies. In Malaysia, crews are optimizing TBM advance rates under high cover with custom-built continuous conveyors, all while tracking disc cutter wear using remote monitoring systems. Learn more about our latest developments at the Robbins stand J1-J2, which will feature interactive media and will be staffed by knowledgeable international employees.

Robit Rocktools Ltd.	G5
Sandvik Mining and Construction	G1, G2

Sandvik Construction is a business area within the Sandvik Group providing solutions for virtually any construction industry application

encompassing such diverse businesses as surface rock quarrying, tunnelling, excavation, demolition, road building, recycling and civil engineering. The range of products includes rock tools, drilling rigs, breakers, bulk-materials handling and crushing and screening machinery. In 2011 sales amounted to more than 9,000 MSEK, with approximately 2,600 employees (pro forma rounded numbers).

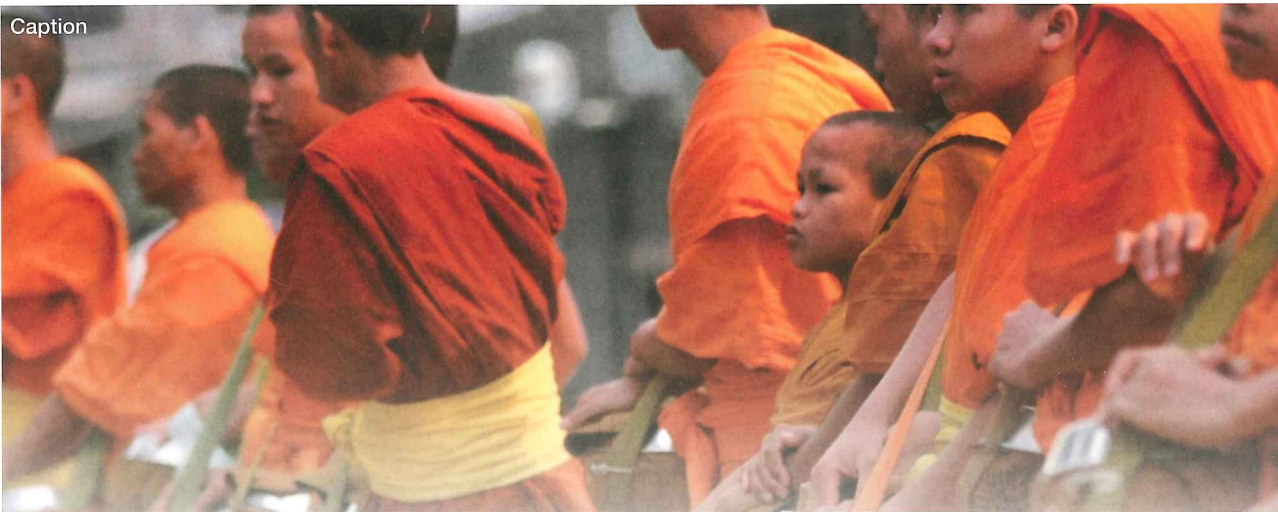
Schauenburg Tunnel-Ventilation GmbH	G4
Seli S.P.A.	I1, I2
Shanghai NACO Lubrication Co.,Ltd.	K4
Sika Sverige AB	A1, A2
SISGEO International	S3
Stirling Lloyed	G3
STM Construction Equipment Pte.Ltd.	N3
Strukton Afzinktechniken	H4, H5

Strukton Civil is a specialist in immersed tunnels. We advise, develop, realize and manage immersed tunnel projects; together or separate. From the initial planning phase to the ultimate immersion operations. Total solutions in every phase of the construction chain.

STS Swiss Tunnelling Society	L1
TAC Corporation	U4
Talleres Zitron, S.A.	L2, L3
Terratec	U2, U3

TERRATEC is the world-renowned Australian designer and manufacturer of Tunnel Boring Machines, Raise Boring Machines and other custom-made products for tunnelling and mining applications. TERRATEC TBMs range from 0.6m to 10m in diameter. Being pioneer and specialist in Hard Rock Cutting Technology, TERRATEC is also very active in the Soft Ground tunnelling business together with its partners MHI and IHI from Japan, for the supply of the most developed and reliable EPB and Slurry TBMs. TERRATEC's scope of work extends to include the operation and maintenance of the Equipment during the execution of the tunnelling works, by its own Field Service Department, as well as the supply of auxiliary equipment such as Rolling Stock or Continuously Advancing Conveyor Systems, which the Company has been supplying in the Industry for the last 20 years. Today, TERRATEC is well placed in the growing global tunnelling market, with its Head Office in Australia, but having subsidiaries in China, India and America to attend its ongoing projects in these Regions.

TOPOMETRIA Ltd.	K3
Trelleborg Ridderkerk BV	U1
Trox Company	M3
WBI Worldwide Engineering	H1



Caption

Clint Cearley / Shutterstock.com

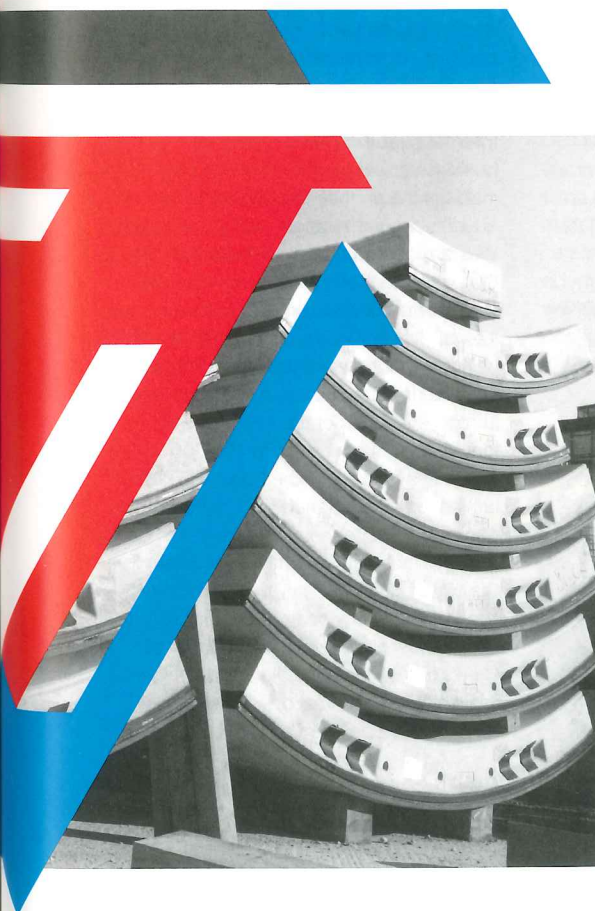
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Sealing Technologies



Many ideas make light work, cheaply

The lighting industry as a whole, including small specialist sectors such as tunnels, has been undergoing great changes in the last decade. Changes in light source technology, more product suppliers, low energy and maintenance requirements, and even the design of longer and wider tunnels are the leading factors in a sometimes confusing array of procurement considerations. Maurice Jones tries to unravel some of the major trends

Maintaining safety whilst keeping running costs down is a major and growing concern of tunnel operators, and to some extent this includes metro companies, mines and other managers of underground space. Riding into this scenario has come the 'White Knight white light' of the large LED, the heralds of which often seem to promise to sweep away all cost problems with the capabilities of low power requirements, low maintenance, long life and easy replacement when required.

In tunnel lighting, as in other equipment, the buyer must be aware of unfulfilled promises and hidden problems. In the right situation LED luminaires have certainly been working well so far. It is early days, however, and some experts advise caution, chiefly on technical grounds (see comment, page 64). And there are, of course, alternatives. The excitement over LEDs has overshadowed the possibilities for induction luminaires. Another recent development with fewer sources, this type of lamp has a much longer life of up to

100,000 hours claimed for it and so running lower costs. Both induction and LED luminaires are currently more expensive in unit cost than the previous favourite of high-pressure sodium lamps and, of course, standard fluorescent tubes. Sodium lamps still have their proponents for long, fast highway tunnels, and fluorescent lights can still have an important role in pedestrian areas of underground stations.

Lights from the East

A major characteristic of the lighting market is the huge number of very similar LED luminaires being made available from many different manufacturers in Asia. These are chiefly located in China but also emanate from Korea, Taiwan, the Philippines, Thailand and other countries. These markets also have varying levels of supplier service support available.

On the manufacturing side, specialist LED makers will supply to luminaire manufacturers and lighting installation engineers. Some leading and more sophisticated lighting manufacturers co-



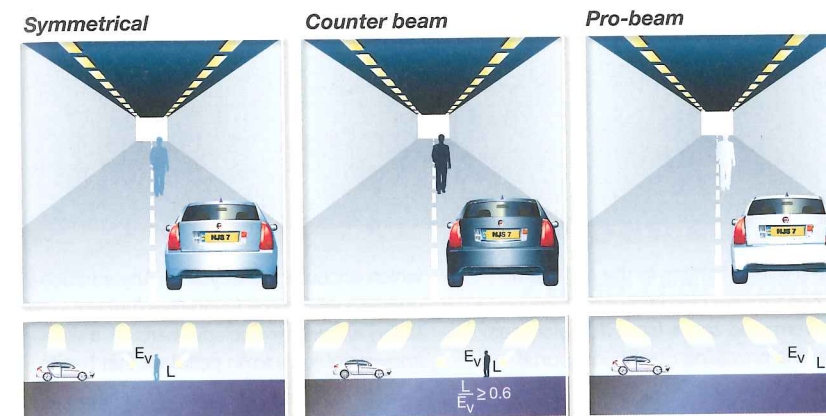
Above: An Osram LED tunnel luminaire from Siteco

operate closely with consulting engineers and architects to offer a full service from concept to commissioning. This applies not only to the West but also Asian countries. In China, in addition to 'off-the-shelf' and Internet suppliers, there are major businesses with many tunnel lighting installations on their record, and also advertising partnerships with some leading Western component manufacturers such as Osram in Germany and Cree in the US.

Western manufacturers are also intensifying R&D efforts into LED devices as well as other types of lighting. One result of this is a dramatic increase in the claimed luminaire lifespan of the new types of induction lighting; i.e. up to 100,000 hours.

Cree says that its 'The Edge' LED tunnel luminaires are designed for 100,000 hours to reduce maintenance requirements. Lamp replacement was becoming a problem for the city of Arezzo in Italy in its Crocina Tunnel, so the city searched for more economical options. By installing 21 of Cree's 'The Edge' triple light bar luminaires it is claimed that Arezzo will see energy savings of 61 per cent as well as improved

Left: Two views of Arezzo's Crocina Tunnel in Italy showing (left) before with HPS lighting and (right) after installation of Cree The Edge LED light bars for improved and cost-saving lighting



Left: Figure 1, the importance of illumination orientation to contrast and obstruction identification

'hole effect' can occur if the level of tunnel lighting is not smoothly graduated between exterior conditions (time of day or weather) and the tunnel interior. Other undesirable conditions that must be avoided in the tunnel are glare and flicker, through inadequate luminaire positioning and frequency, and insufficient contrast that can make it difficult to notice potential obstructions in time. A driver distracted and confused by uneven lighting, or unsure of what is ahead, is not a safe driver.

Fortunately independent design guidance is available, particularly for highway tunnels, through the International Commission on Illumination (CIE) through its technical report 88, revised in 2004, titled 'Guide for the Lighting of Road Tunnels & Underpasses'.

The basic concept is to split a tunnel (if of sufficient length) and its portal zones according to the required luminance. The transition curve between these levels of luminance should also be as smooth as possible. The lengths of the access and exit

lighting. Cree has also supplied numerous tunnel installations in China.

Testing times

Faced with a marketing onslaught, many operators and their consultants have wisely sought independent verification before investing too much faith and money in new designs. In France, the AREA/APRR Autoroute operator and consultants EGIS Tunnels have conducted on LED lighting in the l'Epine tunnel on the A43 autoroute. The programme was designed to be completely independent of possible lobbying and 'fashion effects'. A general conclusion of the tests was that LED luminaires could be an interesting alternative to the commonly used high-pressure sodium lights for tunnel base lighting. However, the authors say that, at the time of writing, LED technology remains new and still in progress and optimisation. They claim it presents a high complexity and enhanced risk in all project phases.

Even in China, words of caution have been issued in various blogs on the subject of LED lighting and the claimed excessive development for street lighting. Seemingly

adding fuel to this the Chinese government's Ministry of Finance Joint Development & Reform Commission with the Ministry of Science & Technology, recently announced subsidies for qualifying LED manufacturers to promote further development of LED street lighting with the objective of lowering unit prices.

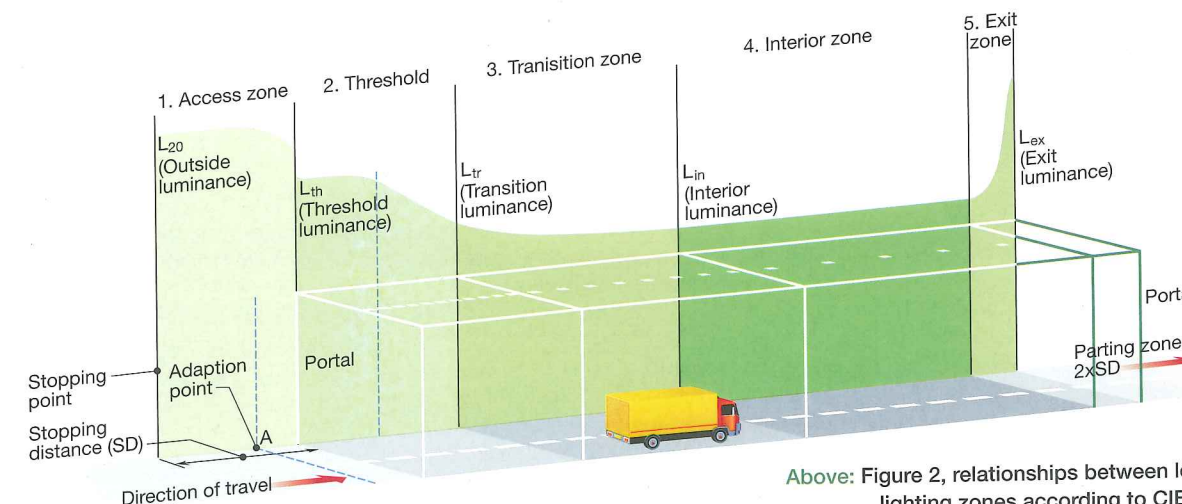
Shandong Liaoyuan sales director Caixing Mao recently says that, as pilot projects of a few hundred luminaires have become popular among local authorities, orders are now into the tens of thousands of units, greatly heating up the market. He reports that his company's orders were three times more than for the same period last year.

Independent reference

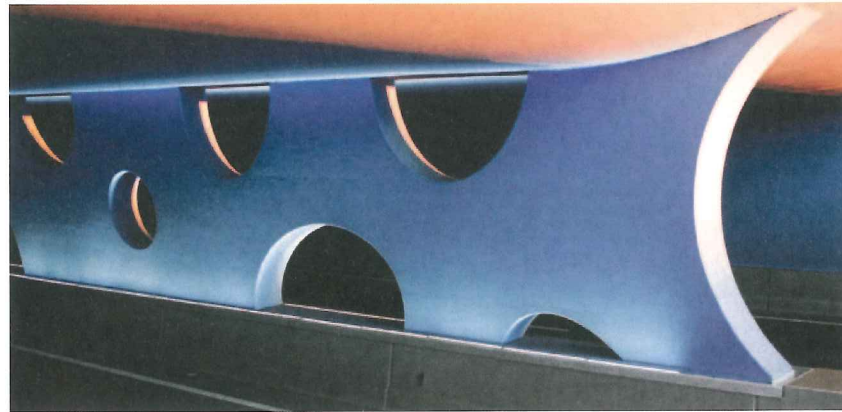
Designing an appropriate lighting scheme for underground use is no easy matter. Even if a decision is taken not to light a road tunnel due to infrequent use, drivers can find this very daunting and need to approach the tunnel with caution, even if only to allow time for eyes to adjust to the change in light.

Similar problems, known as the 'black

Below: Counterbeam lighting at the Aiguebelle Tunnel portal in southeast France using Schreder FR4 luminaires with 400W HPS lamps



Above: Figure 2, relationships between long tunnel lighting zones according to CIE guidance



Right: Merging lighting with architecture can be done in road tunnels – here in the tunnel under the Aquaduct de Geeuw in Friesland, Netherlands. It uses Philips white-light LEDline fittings and Luxeon RGB decorative lights. [Photo credit: Philips and architect Tatjana Trzin]

zones depend on the design stopping distance of vehicles using the tunnel.

Induction alternative

As mentioned previously, the alternative of induction discharge lamps has been somewhat overshadowed by the wide availability of LED lighting. Both are cheaper to run than the most common existing luminaire type of high-pressure sodium (HPS) discharge lamps. The Chinese manufacturer HongYuan of LVD induction lighting has issued case history data comparing the performance of both HPS and LVD lighting due to renovation of the Yanlieshan North Tunnel. Using LVD induction lights having a life expectancy of 60,000 hours, the annual electricity cost saving achieved was 62.4 per cent, or CNY 1.078M (USD 170,880) even allowing for maintenance, compared to the previous HPS lighting. This was derived from a power saving of 1,221,954kWh per year. The induction lamps also give a whiter light compared to the more yellow sodium lighting, giving a better indication of true colours in the tunnel.

A small drawback of induction discharge lamps is that, like earlier discharge lamp designs, they incorporate mercury in their mechanism causing possible disposal problems. However, the amount is relatively small and with the greatly extended life of the lamps, the problem is minimised.

Control

There is more to tunnel lighting than installing some new lamps. How do you make sure they are all operating correctly throughout the day, for maximum safety and economy? For most busy traffic tunnels, physical inspection is out of the question due to operational disruption and cost, as well as opening operators to ridicule about 'how many tunnel workers does it take to change a light bulb'. The answer is one of the recently developed intelligent control and monitoring systems.

Scanlight AT, produced by the combined work of P. Ducker Systems (PDS) and TRT Lighting includes Digital Addressable Lighting Interface (DALI) individual control and interrogation facilities on each luminaire. It allows the central control

system to dim lighting to the minimum required for safe operation in the predetermined zones (see CIE guidelines) under the prevailing conditions (portal luminance). It also permits each fixture to be interrogated to determine whether it requires maintenance attention or replacement. This avoids unnecessary inspections, which could disrupt normal tunnel operations.

Nyx Hemera Technologies' leading product is the Tunnel Lighting Addressable Control System (TLACS). Its first application was the second phase of a control system for the Kallang-Paya Lebar Expressway tunnel in Singapore.

Wall role

The surfaces of a tunnel can play an important role in the distribution of light within the tunnel, perhaps saving on luminaires but perhaps more importantly the quality of the luminance. This subject is also covered in the CIE technical report guidance and in Australia has a standard, AS1158.5, that specifies surfaces should be perfectly diffusing (see feature, page 71).

Various materials have been used to promote the required reflectance including prefabricated panels, sprayed coatings, tiles and special concrete mixes. Apart from the purely functional aspect of reflective walls, the lighting design has sometimes become an integral part of underground space architecture, particularly for pedestrian use, so as to make the space more interesting and welcoming. This has even been the case in some transport tunnels. Concerns about the length of the Laerdal Tunnel in Norway, the longest road tunnel in the world, affecting the concentration of drivers led to research by SINTEF about ways of creating more interest to promote safety.

This resulted in the inclusion of several rock caverns along the route and colour lighting schemes.

Green to the end

The drive for sustainable or green lighting correlates with running costs savings that can now be achieved, but it doesn't end there. Many countries have controls on the disposal of electronic and electrical goods,

which encourages recycling. Any additional concern with some luminaires (but not LEDs) is that they include mercury, a well-known potential toxic pollutant that has to be disposed of with care.

Choosing suppliers

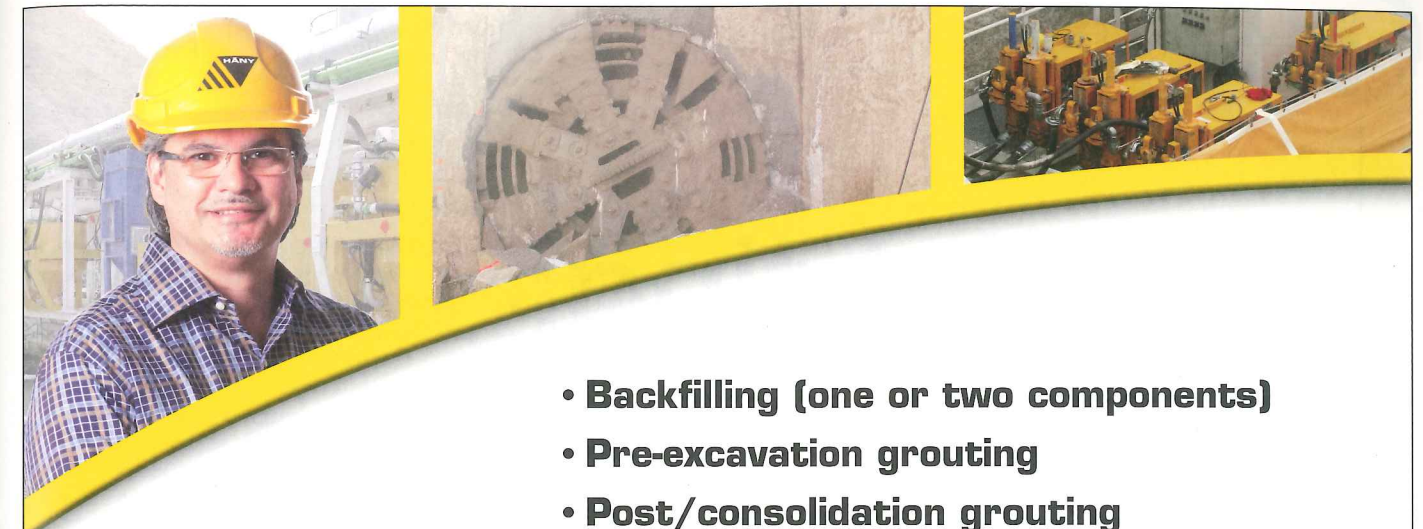
Clearly the factors involved in purchasing tunnel lighting are many, matched in numbers only by the possible sources of luminaires. These could even be purchased via the Internet from Asian manufacturers and trade websites. Established manufacturers in the 'West' such as Philips and Osram are said to be under pressure from the pricing and availability from the 'East', particular in LED lighting, but can fight back with their strong points of installation expertise and co-operation with a network of architects and specialist independent lighting engineers, plus general service support.

Indeed even some manufacturers and installers in China list western manufacturers such as Osram and Cree as partners. In between there are many lighting product distributors. ■

Further reading

- BSI British Standards Institution, BS-5489-1:2003 + A2:2008 Code of practice for the design of road lighting. Lighting of roads and public amenity areas.
- BSI British Standards Institution, European Standard EN 13201 'Road Lighting'
- International Commission on Illumination. CIE 88:2004 'Guide for the Lighting of Road Tunnels and Underpasses', 2nd edition, ISBN 3 901 906 31
- Martinetto, O, Gachet, J-C, & Courajoud, F. Tunnel lighting using LED: Results from tests in situ, AFTES Congress, Lyon, 2011.
- Schreder 'Tunnel Lighting – Expert Solutions' brochure, Schreder Group GIE – Comelec, Brussels, Belgium
- Thorn Lighting Holdings. 'Tunnel Lighting' handbook, Borehamwood, England.

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LED lighting: pitfalls, problems and common sense

A call to arms for lighting designers. Rick Morrison, principle engineer in specialist lighting for Aecom Australia, based in Queensland, comments on the explosion in LED popularity and lays out some common sense rules to follow when considering LEDs – for tunnels or otherwise



Above: Rick Morrison of Aecom calls on lighting designers to lead the charge with LED lighting and ensure the right solutions are chosen

All aboard, tickets please roll up, roll up, roll up! I'm off on the next lighting bandwagon, LED lighting.

I remember the last great lighting bandwagon, hydrogen dichoric, generated out of the 1980s. These little display type lamps are now resident in the world's housing in plague proportions. Installed by a self-congratulating horde of manufacturer's agents, under the mighty banner of green, energy efficient and reduced lighting load. Not just in houses,

but spread all across the interior lighting scenarios of the 1980's, supermarkets, luxury hotels, yachts, and even in offices, receptions and toilets.

I still fondly recall the jingle boom sounds of the 'snake oil caravan' at the end of the street corner. I stand guilty as charged amongst them now. Yes, I sold halogen as the ultimate new technology capable of improving the bottom line, and restoring the green balance. There was little real energy saving available by using halogen-lamps, they were only about 15 to 20 per cent better than incandescent lamps. The only real efficiency was in applying lighting in a focused way, like in retail merchandising. The product became a fashion, and soon the lighting industry was applying this misunderstood technology to all or every type of application.

So fast forward 20 years or so and see that glow on the horizon now. Not the early morning sun catching the Sultans Tower in a noose of light (apologies to Omar Khayyam). No, it is the glow of the tidal flow of new LEDs for the lighting industry.

Yet another bandwagon, and this one is no different.

LEDs are becoming fashionable. Drop them into conversation. Just mentioning them at design meetings will earn you points. As with all fashions, the heat is on to use LEDs. The snake oil salesmen are doing their work well. Nearly everyone is convinced, except of course the skeptical lighting designers. The real difference this time around is we can take better care at the design end of things. Are we not wiser since the halogen fiasco of the 1980s?

Houses were burnt down from poor installations, shops' air conditioners overheated from the many transformers located in tiny cupboards, and people were personally injured by the glare and heat.

In a growing movement of common sense proportions, educated lighting designers are beginning to understand the truths behind the technology, and to set upon the task of establishing rules of play. The bright way forward! There will always be, and have always been, 'snake oil' sales people who can sell ice to Eskimos.

But this new fashion craze for LEDs must be tempered with common sense engineering attitudes.

Dangers of choice

The big problem with this new light source is that anybody can peel the label off a soup can, drill a hole in it, and stick a glowing LED in place, and claim to have a light fitting. So many new LED products arrive on the market looking very like a neat and tricky new 'throw away toy'. Marvelous industrial design and beautiful aesthetics – while incredible claims about LED life, lumen output and performance are made. However, upon the extinguishment of the LED source the whole product is thrown to land fill. Even if it has some recyclable components, the intrinsic or embodied energy in the product is discarded.

The reality of modern design thinking must always involve a very practical use of any lighting technology. Rather than a throw away economy, lighting designers are thinking about replacement and re-use of all hardware. Very clever manufacturers are

providing products with replaceable LED segments so the light source can be changed. The housing might stay in place for the lifespan of the retail shop, or for the life of the hotel fit out, or in the case of tunnel lighting, stay in place in the ceiling mounted lighting array for many years, even decades while the LED sets are replaced upon failure, and the control gear upgraded when it too fails.

This is the key point. The hard-won extracted metallic resources used in making the housing and reflectors are used and re-used, and cleaned perhaps and re-used again.

Laying down the law

This is sustainable thinking. This is green, and is very definitely 'low carbon'.

It is not about the snake oil man selling his miracle cure of LED potions and spinning almost unbelievable claims about performance efficiency and so on. It is about careful choices of technology:

- Replaceable LED sets (pucks, racks or

arrays) – changing the light source, not the light fitting

- Maintainable housings – designed to a quality that lasts many LED set changes
- Temperature test data – relates to continuing performance of the LEDs
- LEDs operated at median milliamp settings to lengthen life – not overrun to squeeze out high performance statistics at the expense of lifespan
- Sophisticated control gear that monitors temperatures, and adjusts the LED voltage accordingly
- Careful selection of control gear and switching, matched to LED and printed circuit board to ensure continuing performance
- Choice of LED chips from high quality established manufacturers (that will be here in 20 years)
- Suppliers that 'BIN' test their LEDs, and document the output to clients for future re-lamping quality
- Certified photometric reports, providing absolute photometry based upon a

particular type of equipment

- New improved LED sets that can be fitted to older existing housings.

Final thoughts

All of this applies to LED technology in tunnels. The biggest challenge in tunnels outside Europe in the warmer climates is the high temperatures prevalent in the ceiling/roof spaces. LEDs are highly temperature sensitive. This factor alone may prohibit LED technology from such places as Australia, Africa, and other subtropical regions.

The use of LEDs is successfully achieved in cooler and darker climates such as in Holland. Nevertheless, the rules of play outlined above must be enforced by lighting designers.

Lighting designers – call to arms! Follow these rules and impose them on your suppliers.

It will be a better world as a result. And we can all be part of a successful and sustainable product roll out.

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The drive to save on light energy

Lighting is a key factor in minimising transport tunnel operating costs whilst maintaining or improving safety. New designs of low-energy, low-maintenance luminaires promise much, but equally important is how they are installed and used. Maurice Jones checks out some of the latest installations

Saving energy and maintenance costs on lighting need not be a matter of putting up with twilight-like conditions and missing bulbs. Using new types of luminaires and control systems is only part of the task since luminaires, both older and new types, still have to be installed and controlled correctly to ensure safe conditions for tunnel users.

Siteco Beleuchtundtechnik, an Osram business involved in tunnel lighting design and installation, has been involved with the first tunnel installations of LED luminaires in Germany and elsewhere in central Europe, but also supplies earlier types of luminaires as required by both the tunnel conditions and operators.

Austria sodium

On the A7 Muhlkreis motorway in the Linz/Bindermichl region of Austria, an artificial tunnel has been constructed by lowering the carriageways to minimise noise pollution on the neighbouring areas. The A7 carries high levels of traffic to and from the A1 West motorway. Siteco developed the lighting concept for the new tunnel and associated roads in what it

describes as the most complex road construction project in Austria to date.

The project includes a three-lane motorway with a hard shoulder in dual tunnel tubes in two lengths of 1,062m in Bindermichl and 580m in Niedermhart, as well as modernising the feeder highways. The new lighting installation consists of 1,543 Siteco NIRO tunnel luminaires with stainless-steel (NIRO) structure and high-pressure sodium elements, and 125 Siteco emergency guidance luminaires for rapid evacuation, also in stainless steel.

In the Bindermichl tunnel the luminaires are mounted in parallel trunking systems. The corrosion-resistance of the stainless steel case is enhanced with safety glass and an additional protective coating. The luminaires have an IP66 protection rating against foreign matter and impact.

The tunnel approaches are equipped with different Siteco luminaires including 126 NIRO custom luminaires within a dynamic traffic control system and recessed within lateral concrete surfaces and bordering the cycle and pedestrian route around roundabouts. The consultant for the project was Austrian Wagner & Partner Ziviltechniker.

One of Siteco's projects driving the application of LED luminaires was the Porzberg Tunnel in Thuringia, Germany, opened in 2010. This employs 185 LED luminaires located in offset positions in the tunnel to achieve maximum homogeneity of lighting intensity.

First LEDs

Osram LED tunnel lighting has been used in Germany ever since the first installation in 2008 for the Thuringer Schmuckettunnel on

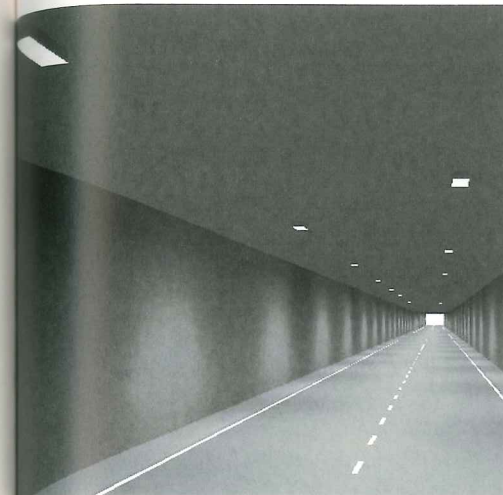
the A71 highway. Dellux Technologies of Canada selected Osram's Golden Dragon LEDs for luminaires specially developed for tunnels. The LEDs are claimed to use 30 per cent less energy than the usual 70W high-intensity discharge lamps thanks to LED degradation compensation technology patented by Dellux. The working life of a minimum 130,000 hours (15 years), is said to be virtually maintenance-free.

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Illumination in the tunnel can be varied as the semiconductor light sources can be dimmed and controlled according to the time of day and other ambient conditions. The required day luminance in the Thuringer Schmuckettunnel is 4.65 candelas per square metre (cd/m²) but at night a value of 0.8 cd/m² is sufficient as determined by exterior available light. This requires a power consumption of 70W during the day but only 12W at night.

The intelligent lighting concept developed by Dellux and used in the Schmuckettunnel employs customised electronic circuitry and software to increase the life of the system. "We have installed redundant LEDs in each luminaire to offset soiling and degradation losses," said Wolfgang Medenwald, VP for business development in Europe for Dellux Technologies. "We also operate the LEDs at only 85 per cent of their rated current to achieve greater efficiency and durability. Our patented light degradation compensation technology allows us to maintain the required light levels for a minimum of 15 years despite the difficult conditions in the tunnel."

More recently Germany-based LI-EX used Osram LEDs in lighting for the new Stachus Passagen in Munich's Karlsplatz to access the S-Bahn and U-Bahn station. Important aspects of the lighting design by the Schmidt-König planning office were lamp longevity, low service costs, space



Above, left: A computer-generated image of the Porzberg Tunnel lighting showing the uniform illumination from offset Siteco LED luminaires; Above, right: View from above to a brightly lit, but economically lit underground area of Munich's Karlsplatz metro station

saving, high output, and meeting defined light-radiating characteristics. In such an installation with close public use, the architectural aesthetics of the installation were also important. The LI-EX profiles employed 65,000 LEDs of two different types. Facade and entrance lighting uses 15,000 cold-white Golden Dragon Plus LEDs for even illumination without scattered light or dazzle with low power consumption. The lighting provides natural colours for a higher level of safety. The 700m-long handrail of the entrance staircase (see photo, below right) uses 50,000 warm-white TOPLEDs in the LI-EX profiles that permit individual length adaptation to suite the different lengths of staircases. Some 18m of handrail illumination require only 100W of power.

LI-EX is part of the 'LED-light for you' network initiated by Osram to work jointly with customers on implementing lighting solutions using LEDs.

Hindhead and more

A new company, TRT Lighting, has inherited the list of highway tunnel application in the UK, Ireland and abroad, including many motorway tunnels, and the recently opened A3 Hindhead Tunnel as the longest land-based tunnel in the UK at 1.83km of twin bores. TRT is also continuing the long-standing co-operation with PDS (P. Ducker Systems) using the jointly developed Scanlight Tunnel lighting control system.

Scanlight was selected to control over 1,800 SON high-pressure sodium discharge lamps in the Hindhead Tunnel. The system works via a multi-channel controller area network (CAN bus) 'backbone' feeding the dual-layered Digital

Addressable Lighting Interface (DALI) circuits for individual luminaire checking. The SON lamps used for boost, basic and night lighting are said to be the most efficient and most cost-effective lighting for a high-speed, long-length road tunnel. By virtue of the lighting layout and Scanlight control, either bore of the Hindhead Tunnel can be run in contraflow, allowing maintenance to be carried out in the alternate bore, whilst avoiding diversion of traffic through neighbouring communities without major roads.

Other major projects employing Thorlux lighting include the immersed-tube Limerick Tunnel for the N18 in Ireland, the Heathrow Airport Airside Tunnel, and refurbishment of the Bell Common Tunnel (M25) and Hatfield Tunnel (A1).

Shenzhen Highway

US-based Cree has one of its strongest markets for its LED lighting sources in China. Last October China completed its largest highway lighting upgrade, on the Shenzhen highway, featuring more than a million Cree XMap XP-G and XP-E high efficiency white (HEW) LEDs. The project included Dameisha Tunnel within 75 miles (120km) of highway.

Kingsun Optoelectronic, a leading LED light company in China, selected the Cree LED lamp to comply with China's highway lighting requirements for efficiency, brightness, luminance, heat dissipation and service life. The highway, including the tunnel, has three lanes and an emergency lane in each direction. Kingsun anticipates

Stairway lighting to Munich's Karlsplatz metro station installed by LI-EX using Osram LED units

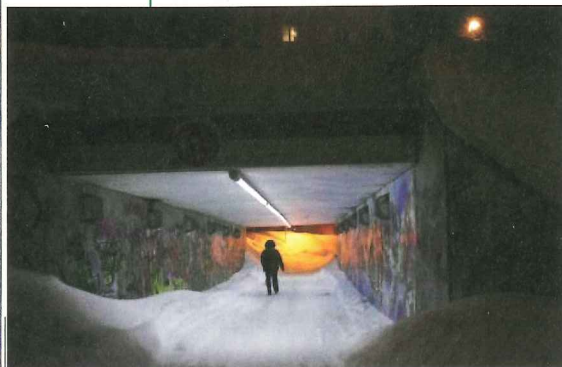
a 60 per cent reduction in energy consumption compared with the replaced, high-pressure sodium fixtures. According to the energy management contract (EMC) business model implemented by Kingsun, the energy savings to be achieved by the Shenzhen Highway Project have an estimated payback period of four years.

Lightpipe

BB Lighting Concepts of Sweden and the Netherlands has installed its low-energy LED-Lightpipe lighting product in many pedestrian and cycle access tunnels, but is now turning to its first traffic tunnel in Liege, Belgium, having won the work on the basis of low maintenance and long life.

February 2011 was a busy time for BB Lighting Concepts. The work included the testing of new and existing installations in various pedestrian and cycle tunnels and underpasses in Sundsvall, Sweden, plus the Balder garage. The testing demonstrated excellent cold-weather





Above, top: A BB Lighting Concepts LED Lightpipe installation in a pedestrian tunnel with Amsterdam's Schipol Airport; **Above, bottom:** LED Lightpipes installed by BB Lighting Concepts of Sweden in a pedestrian underpass in Sundsvall. The installations also prove low ambient temperature performance

performance (down to -20°C) of the companies LED Lightpipe product compared to fluorescent lighting fixtures, the output of which reduces in freezing temperatures. For example, a tunnel fitted with 500W fluorescent lights was replaced with Lightpipes of about 385W consumption. The light output was shown to be sufficient, allowing the light output to be dimmed using DALI controls. Energy savings of up to 84 per cent were achieved compared to original installations.

A similar renovation replacement was carried out in a car park in Harlingen in the Netherlands where the LED Lightpipe Stand-Alone was used, allowing the original wiring to be retained.

Italian LEDs

The first opportunity for AEC Illuminazione to demonstrate its competence in LEDs was presented by forward-thinking highway management operators for redevelopment.

AEC offered its TLED luminaire specifically developed for tunnel lighting interiors of which AEC has installed nearly 12,000 luminaires.

Most of these have been installed in major motorway tunnels such as the A1 between Florence and Bologna including the Le Croci di Calenzano tunnel in Tuscany, and the A12 between Tuscany and Genoa. TLEDs have also been installed in underpasses and urban tunnels.

Light perceptions

While there is widespread recognition of the importance of well designed tunnel lighting schemes in such functions as preventing glare, graduating illumination between the interior and exterior at different times of the day, and the changes brought about by emergency situations (including signage), in recent years there has been a lot of work on effects of different types of lighting on the facilities users, not least in tunnels and metro stations. The introduction of LEDs to public space lighting has tended to increase the alternatives available, not just for general decoration, but also to make the space safer and more comfortable for users, depending what they are doing e.g. driving, walking, waiting. Some aspects of these are covered in the article on page 60.

Examples of the imaginative use of LEDs are presented by the Malmo City Tunnel in Sweden, described on the Stylepark design web-site as making 'a subterranean world of light through the symbiosis of light and space'. The new central railroad station, and two other stations at Triangeln and Hyllie, were designed to make it easy for travellers to find their bearings and to convey a sense of security.

The stations' illumination employs Durlum LED products in designs developed by architects KHR Arkitekter, SWECO, and Metro Arkitekter. Within the underground section of Triangeln Station, light controls were designed to simulate natural daylight, since daylight could not be projected to that part of the station. Large LED panels illuminate the platform areas, plus indirect lighting covers the curved tunnel walls in white light. Brightness is adjusted according to the weather and time of day.

Indirect lighting is even more important at the Malmo C station where reflective ceilings made of textured aluminium are particularly important to cast indirect dazzle-free light across the tracks. At the Hyllie station the emphasis is on natural indirect lighting using faceted mirrors to spread light with an even intensity.

Big Dig big bill

The costly consequences of incorrect lighting choice are being demonstrated by the Boston I-90/93 CA/T project, otherwise known as the 'Big Dig'. In this case it is not



Above: Part of the underground section of the Copenhagen central station feature Durlum LED lighting

even a matter of energy consumption and light output that is the main problem, but the often-overlooked consequences of corrosion. Corrosion can attack all tunnel fixtures, depending on the materials used, whether through groundwater leakage in old or inadequately waterproofed tunnels, or from chemicals within the tunnel such as salt/brine, antifreeze and chemical spillages. In the case of the Boston 'Big Dig' tunnels corrosion has attacked the lighting fixtures resulting in some failures and falls from the tunnel ceiling.

As the Massachusetts Department of Transport (Mass DOT) is promoting a lighting replacement programme costing around USD 54-55M, transportation secretary Richard Davey has said that the proposed LED lights with polymer fittings will not deteriorate long before their expected lifespan. The 25,000 existing fittings, fluorescent units with metal fixtures, were supposed to last 30 years following purchase ten years ago, Mass DOT officials say, but one fell to the traffic lane during February last year. Since then they have been held up with double plastics straps and inspected regularly. The proposed LED light sources themselves are expected to last 12 to 15 years compared to two years for a fluorescent fitting.

The weak point of the original luminaires, made by the now defunct US-based NuArt company, was quite detailed. A clamp needed to ensure watertightness actually cracked the protective powder coating on steel, allowing corrosion of the latter from salt spray.



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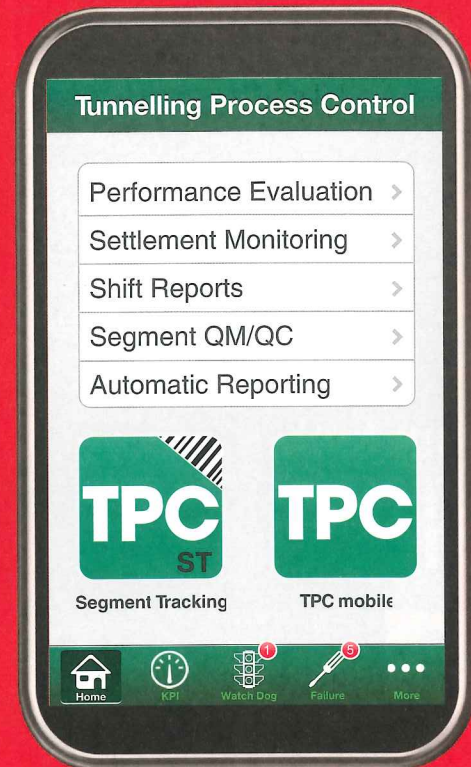
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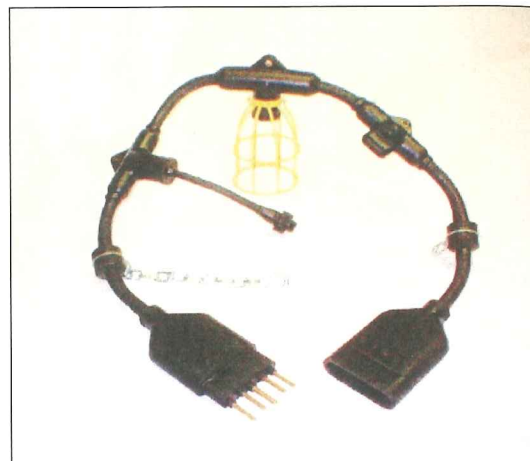
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Wall lining and luminance tests

Lighting design for transport tunnels is defined in Australian standard AS1158.5 (2007) 'Lighting for Roads and Public Spaces Part

Five: Tunnels and Underpasses', and also in European standard CIE 088:2004 'Guide for the Lighting of Road Tunnels and Underpasses'. In these standards the nature and quality of the interior wall linings is described. In AS1158.5, section E4.4 dictates that surfaces other than the carriageway in the tunnel lighting model shall be perfectly diffusing (i.e. lambertian), while the European standard CIE88 does not specify a surface reflective quality.

It can be seen from the case history tabled herein, that the nature of tunnel wall linings is not accurately understood and that the potential for reflected glare from vehicle headlamps is affected by the overall performance of the interior reflectance inside the tunnel.

Logan Tunnel

The lighting installation for the Eastern Busway Two Buranda to East Brisbane,

Rick Morrison, principal lighting designer for Aecom in Australia gives this insight on the reflective requirements of a tunnel lining

Logan Tunnel was commissioned on 13 July 2011. Like all modern transport tunnels, the Logan Tunnel was clad with interior wall panels, the characteristics of which were carefully specified in the design documents. The specification called for a minimum of 60 per cent reflectance factor and for the surface to be diffusing (lambertian) in nature.

The application of the reflective panels is intended to provide a higher degree of ambience in the tunnel, improving the visual performance of drivers. With reflective walls the comfort level of the driver is improved, as the dark tunnelling effect is reduced. Comments were received from several parties involved this project as well as the Wellington tunnels alliance that indicated a level of concern regarding the potential for reflected glare from the linings. To better understand the reflective performance of the panels, a

series of test measurements were conceived. A series of luminance measurements were proposed to measure the brightness resulting from headlamp reflectances in the tunnel. This paper tables the results of this case study in the Logan Tunnel.

Method and equipment

The measurement tool used would be the same luminance meter that was being used to test and commission the carriageway luminance values. The luminance meter was a Konica - Minolta LS-110.

The meter was mounted on a staff to provide an observer eye position of 1.5m above the carriageway. The interior lining of transport tunnels is designed to add to the

Below, Left: Vehicle at the portal entry positio. With the experiment about to commence; Below: Graeme Culling of Betacom New Zealand, checking the luminance meter



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Table 1: Luminance Readings in Logan Tunnel (CD/m²) (LB = low beam, HB = high beam)

POSITION	BARRIER LB/HB	CARRIAGEWAY LB/HB	WALL HIGHLIGHTS LB/HB	LOW BEAM	HIGH BEAM
60m	35/40	10/9.5	380/634	1,900	7,800
50m	32/31	10.5/10.3	36/150	3,400	9,400
40m	22/23	11/11.	75/600	6,500	30,000
30m	17/15	11/10.4	45/200	11,300	40,000
20m	11/7.7	10.5/10.7	. 12/65	90,000	100,000
10m	11/7.7	10.5/10.7	. 12/65	no change	no change

reflection of lighting within the space of the tunnel, and is specifically required to have a reflectance value of at least 60 per cent, and in general practice are often supplied in white or light colours. They have an inherent 'gloss factor' – which often provides the added bonus of reflecting the interior of the tunnel ahead of the driver in a way that allows a predictive cognition.

Using a pole mounted luminance meter at 1,350mm height above the carriageway, measurements were set up as follows.

A fixed observation point of 60m inside the tunnel at the drivers' observation position of the lane facing the oncoming traffic lane was adopted. A Mazda Bravo Cab Chassis Ute - 2004 with Halogen headlamps was used in the test. The vehicle was positioned at the start of the portal entrance.

Measurements were taken for luminance on barrier surface adjacent to vehicle, carriageway in front of vehicle, bright spots on wall adjacent to vehicle and the headlamps in low and high beam. The vehicle was then moved 10m closer to observer position and the measurements taken again. Successive 10m moves were taken with measurements until the vehicle was at the 50m point.

The switched level for the tunnel lighting system was Night Switch.

Wall Linings – lambertian or semi-specula

A film was also taken with the vehicle driving from one end of the tunnel to the other in order to capture the essence of the visual scene within. The photographs of the interior scene during the measurements also contribute to the understanding of the tunnel space.

The footage and photos show that the interior lining in the tunnel is not lambertian in reflectance, but of a semi-specula nature.

The published information from Alpolinc Linings indicates the reflectance is split as 30 per cent specula (glossy), and 45 per cent diffuse.

This situation is not mentioned in AS1158.5 (2007) where reflectance is described as diffusing, or in CIE88 (2004), which does not mention reflectance, however it is considered in CIE189 (2010) – where they discuss the inter-reflections in the tunnel.

The author has discussed the possibility of having the wall lining material tested for an 'R' table, with several photometric laboratories and manufacturers with photometric facilities. R tables for wall linings similar to the R tables for road carriageway luminance calculations might be able to be used in radiosity software to improve the accuracy of the design

Calculation of inter-reflection

If no reflection tables are available, the interreflection should be calculated according to Lambert's Law and the inverse square law.

If bi-directional reflection tables for the road surface and the walls are available, the calculation of interreflection can be carried out based on these tables. Because of calculation complexity, different software procedures have been developed to simplify the problem. At present no standard procedures are recommended, therefore no description of this procedure is given in this report.

"The diffuse reflection factors of the surfaces should be evaluated by field measurements if possible. If measurement is not possible, values should be chosen from known measured values of similar surfaces.

NOTE: In some cases the reflection factor may be dependent on the direction of the incident light.

(Extract from CIE189)

Below: This photo shows the specula quality of the wall lining panels. Photo credit: ALPOLIC

process. Whilst the R tables for wall materials can be produced, the software and lighting product companies have expressed doubts as to the usefulness of this due to the narrow field of view (alpha = 1° ? R-Table), wherein the R table is expressed in a one degree field of view as from an observer position – and this would not assist in understanding the fullness of inter-reflected components in the tunnel. So the situation remains that we are estimating the lighting design based on a perfect

Table 2: Logan Tunnel threshold luminance values

	Logan Tunnel
L20 value West portal (cd/m ²)	7,150
L20 value East portal (cd/m ²)	5,441
Threshold value (West portal) (cd/m ²)	358
Threshold value (East portal) (cd/m ²)	272

diffusion pattern to the wall – and in reality are installing lighting with a specula wall surface. There are pros and cons to all situations. The benefits or pros to having a semi-specula surface in the tunnel is

demonstrated (see photo, below), where there is a clearly visible image of the tunnel around the corner for the driver, and this will assist in predictive driving.

Even though the essential point of the

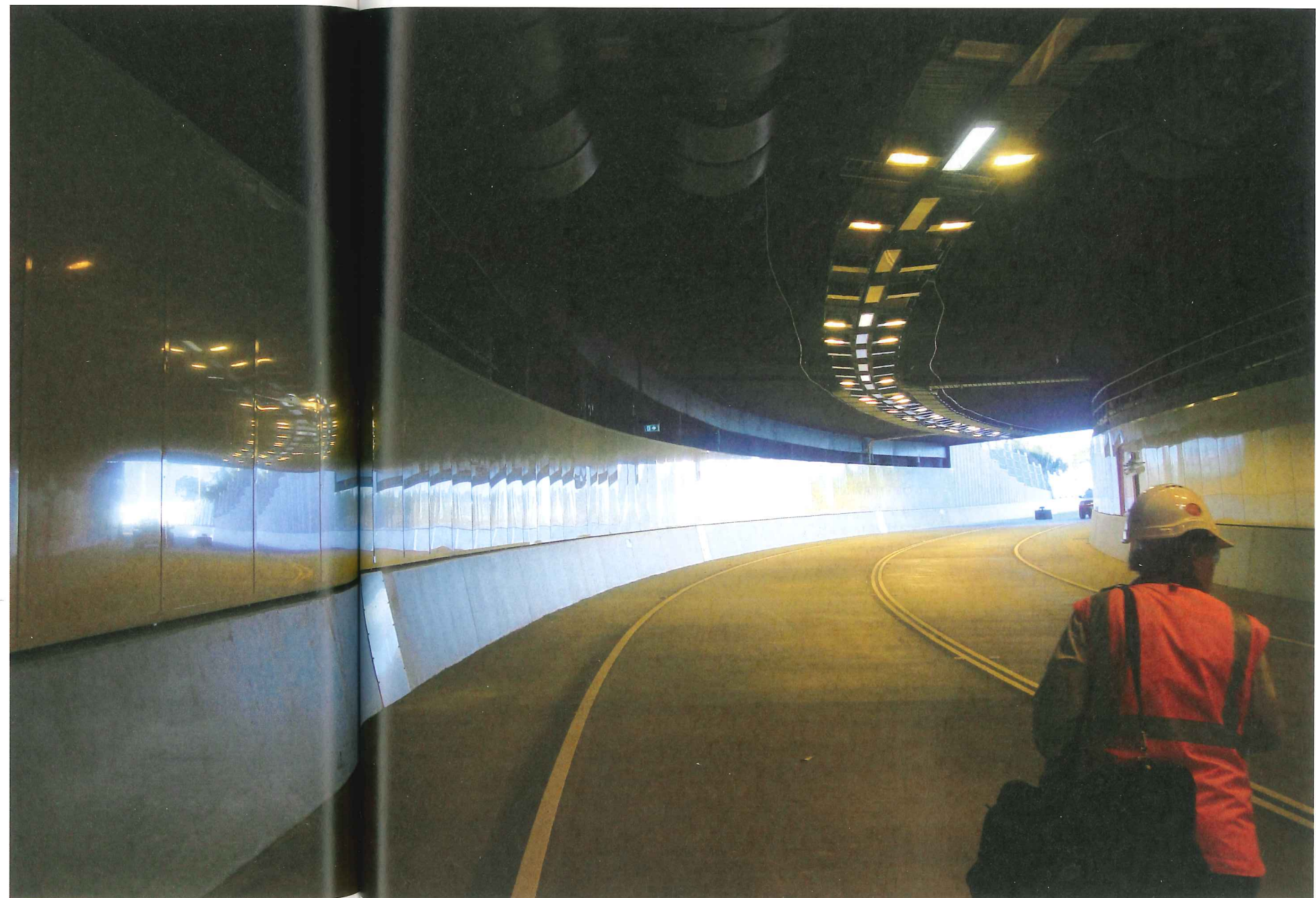


Table 3: AS/NZS 1158.5:2007 – TABLE H1, Sky luminance values

Portal Orientation	Type of Element	Luminance of element (cd/m ²)
North	Sky	15,000
Northeast	Sky	16,000
East	Sky	12,000
Southeast	Sky	9,000
South	Sky	8,000
Southwest	Sky	10,000
West	Sky	14,000
Northwest	Sky	16,000

Note: The above sky luminance values are 90 percentile values measured in Sydney

Table 4: AS/NZS 1158.5:2007 – TABLE H2, Luminance values various types of structural and environmental elements (cd/m²)

Driving direction	Road surface R3	Road surface R1	Building	Vegetation
North	6,000	8,000	4,000	2,000
East-West	4,000	8,000	6,000	2,000
South	3,000	8,000	8,000	2,000

Note: For concrete surfaces use values for buildings multiplied by 1.5. For surfaces in permanent shade these values may be reduced to 25 per cent

wall linings is to improve general ambient visibility and to provide a contrast background for seeing the other vehicles in silhouette, anecdotally the surface of the semi-specular material slowly evolves with continued grime build up, and with cleaning cycles and eventually loses some of the specularity. This however does not appear to have been tested in the field or lab. So once again an intuitive or educated guessing process is used in design. If 'R' tables are too narrow or road observer based to be of use, then perhaps the next best thing would be to have a lab test of wall lining materials produced in various ages of wear in order to allow for a more accurate modelling of the space. Alternatively, if the strictures of the (alpha = 1° ? R-Table) don't allow for a proper study of inter-reflectance, then perhaps the software suppliers can provide revised programs which can take into account the dynamics of specular reflection.

One other perhaps scary consideration is the results of the 'Jacket Frith' report, in which the various carriageway surfaces across New Zealand were tested for luminance performance and were found to be in error.

Using the 3D lighting model of the Logan Tunnel in AGI32 software, the lighting was first calculated with full radiosity (gathering all the inter-reflected light), and then redone with radiosity switched off.

The results are a comparison of direct light only to full inter-reflected lighting. The results show a contribution from inter-reflected lighting of five to seven per cent. This is a significant value. Any improvement in the design and modelling process would therefore enable a leaner design with lower energy consumption.

Comparison data

As a comparison reference point, the following table provides the calculated portal luminance values for the Logan tunnel at the Eastern Busway project in Brisbane, which is geometrically similar in size to the terrace tunnel.

The L20 is the calculated portal luminance of the tunnel as seen by the driver at the safe stopping distance. The threshold value is the amount of compensating brightness in candela per meter squared that is then provided in the portal threshold zone by the lighting system. These values are provided as a

way of gauging the measurements taken in the tunnel.

It can be seen that the apparent and transient brightnesses in the reflected lighting on the wall of the tunnel are in the same scale as the portal entrance brightness values, which are witnessed by the drivers' eyes every day. As another point of reference or scale table 3 and 4 extract from AS1158.5 (2007) provides values for typical luminance of various surfaces in daylight conditions.

Referring to the Jacket Frith report

The testing of 140 sites across New Zealand in 2009 proved that the assumed reflective characteristics of road surfaces are not accurate, and that in the cases studied, the reflectance factors (Q0 and S1) were significantly lower than required.

This means that if the same was true in Australia, and there is no reason to suspect that this is not the case, then we are effectively under-designing road lighting, and perpetrating an error in design that increases the danger of driving on the road.

Mitigating this concern for the Eastern Busway project is the fact that the pavement surfaces produced there were all very carefully specified and manufactured. The reflectivity of these modern carriageways is reasonably certain.

Conclusion

In combination with a complete lighting system audit, the wall linings reflective characteristics were combined with vehicle headlamps and were measured and filmed. The conclusion supported by the tabled measurements is that the brightest things in the tunnel are the vehicle headlamps.

Use of wall linings of a semi specular nature may actually improve the drivers performance in the tunnel, however there is no real understanding of how these surfaces perform in the design, and assumptions are still being used in the design process.

Results of the tunnel lighting audit (to be published separately) have demonstrated accuracy between the design and the installation of less than five per cent margin.

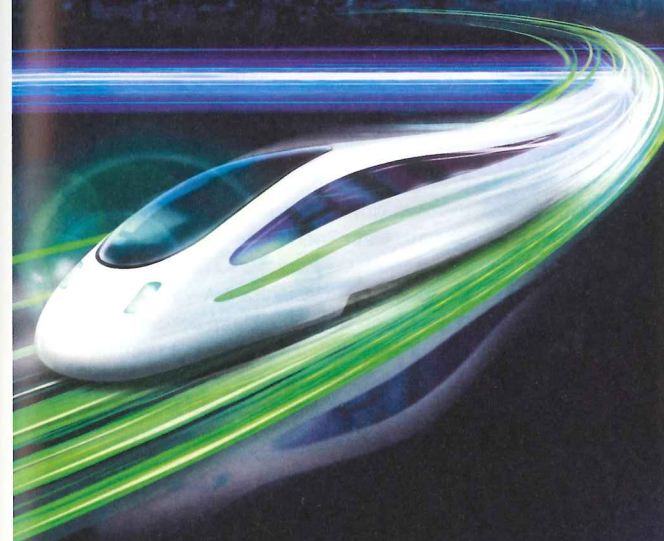
This suggests that the design method used in the Eastern Busway project is intrinsically accurate and capable of handling the many significant variables in the process. ■

Reference

Reflection properties of New Zealand road surfaces for road lighting design, March 2010 – M. Jacket, W. Frith

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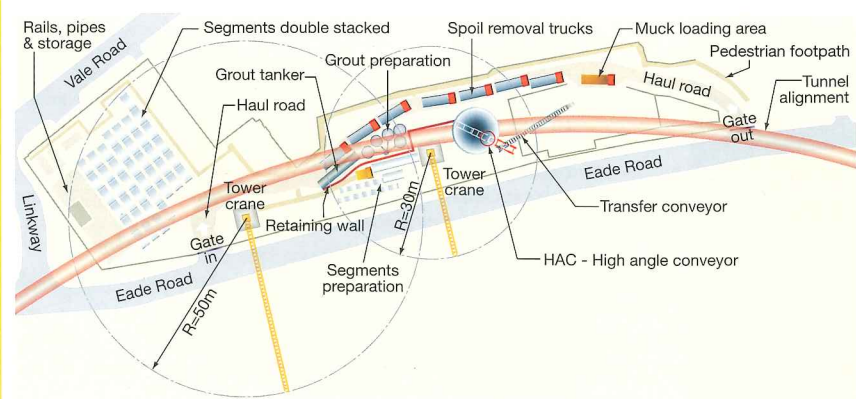
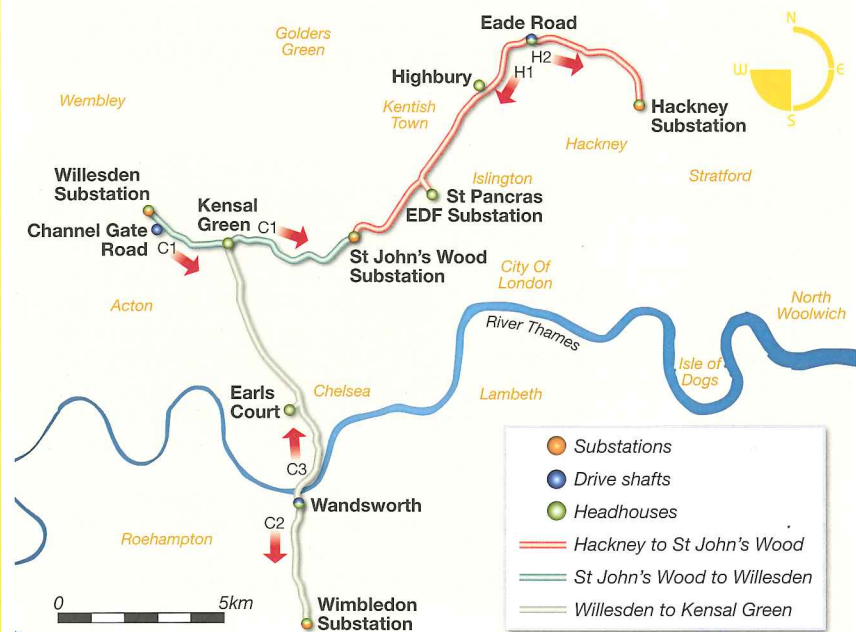
UK gas and electric power network operator National Grid is engaged in a major renewal programme to ensure power supplies for the future. One aspect is to install high-voltage cables underground to renew the grid in major urban areas, starting with London. Maurice Jones visited one of the current tunnel drives in a 32km-long network that started recently in north London

National Grid's Eade Road construction site in Manor House, north London, is one of two main tunnelling locations, each with its own TBM, for the operator's current underground development totalling 32km length of tunnels.

The site, compact and inaccessible, takes advantage of brown-field land created from some land owned by National Grid prior to commencement of the tunnel

works, combined with the a former textiles factory that had to be demolished. The site is on a natural slope. Preparation of the site included some demolition and the creation of a suitable level surface by retained backfilling, and so creating enough storage space. The site is squeezed between a garage, textile and clothing industry factories and warehouses, a residential area and a canal in the Manor House-Haringey area. Not a square metre

is wasted on the site itself, and a clever road traffic handling system ensures a quick turnaround of both materials deliveries and spoil removal to minimise disruption to neighbouring roads. The second tunnelling start site is at Acton Lane, Willesden, where, as T&T visited in mid-March, a Caterpillar TBM has been commencing its first of three 3m-diameter drives. The site will then move to Channel Gate Road.



Surface space

While space within the 200m by 15m Eade Road site is at a premium, it could be considered an advantage that everything is nearby. This enables major material handling to be carried out by two tower cranes with overlapping radii of operation. The larger, with a 50m radius and 7t rated capacity, unloads pre-cast lining segments and other materials from road delivery trucks using a variety of appropriate cradles. The segments are placed, as delivered, in double stacked rows of the same type at one end of the site. This crane is also used to sort the segments into sets of six (five and the crown) to form a ring, the set being carried in one cradle. Once the sets have been formed and space in the second storage area becomes available near the shaft, each is carried over to the second storage area.

The second tower crane has a smaller operating radius of 30m, but a higher lifting capacity of 13t for the heavy installation work that was required to set up the TBM. This crane lowers each set of segments down the shaft for loco-hauled transport to the TBM back-up.

When in full production the TBM

Left, top: Map of the London Power Tunnels in phase one in north and west London with order of drives and main purposes of shafts.

Left: Plan of the Eade Road compound from where the Herrenknecht TBM has been launched on the first drive



Above: Starting to lower Herrenknecht TBM 'Cleopatra' down the Eade Road shaft (looking South) using a 800t mobile crane



Right: Preparing to lower Herrenknecht TBM 'Cleopatra' down the Eade Road shaft.

progress will require a high throughput of road trucks through the site both for materials deliveries and soil removal. With supplies, the target progress of 23 rings per shift at Eade Road, plus a two-ring contingency, will require 150 segments (25 rings) to be delivered on 20 articulated trucks. Grout mix and pulverised fuel ash (PFA) require another two or three road tankers a day to fill on-site silos.

Using the same haul road, but with waiting space for around eight trucks, spoil loading and removal requires 90 tipper trucks a day, even with sufficient spoil storage on site for 36h.

John Trounson, project manager for National Grid UK Construction, tells T&T that although the Eade Road compound is definitely compact, the construction compounds at St John's Wood and St Pancras are even more so.

National Grid has adopted a policy of utilising brown-field sites for new substations and other construction sites wherever possible. In addition to Eade Road and other shaft areas for the London Power Tunnels project in north and west London, National Grid has been cleaning up old town gas sites at Poplar and Bromley-by-Bow in east London to free the land for redevelopment. Soil from the tunnelling has been reused for these.

Purpose

The initial London Power Tunnels project has several strategic purposes for National Grid. Firstly it will renew the aging main electricity supply routes in the capital, replacing cables of old design that are now approaching the end of their life. Secondly it will provide for the continuously changing power needs of the conurbation. And, thirdly it is part of a new strategy by National Grid to link the many new and varied power sources with demand in regional grids rather than along limited main supply lines. The new strategy will facilitate the connection of existing and new power generation sources such as the cross-Channel cable link with France, wind-farms and other renewable sources as we rely less on coal-fired power stations. Thus London and other centres of demand can be fed with power from multiple directions.

Initially the new London Power Tunnels will carry two 400kV bi-directional circuits, although the larger 4m-diameter tunnel between Hackney sub-station and St John's Wood substation is designed for more cables. The tunnel cables will supply various sub-stations along the route including via a spur to the UK Power Networks sub-station at Islington, and the Crossrail power supply via Kensal Green.

John Trounson explains that, considering

the high level of tunnelling activity in the London area at present, National Grid decided to advance its shaft-sinking schedule, partially to avoid any shortage of skills that may be caused by the demands of projects such as Crossrail.

Cranes

Heavy lifting plays a key role in the set up and operation of the Eade Road and other drive shaft sites of the project. This started mainly with the delivery and assembly of the TBM requiring an 800t mobile crane to unload the cutterhead and front can and lower it down the shaft. Once this was moved into the previously excavated stub tunnel, a 140t mobile crane was called upon to install the steering can. Once the initial TBM excavation had been completed, the components for the 127m-long back-up system could be installed.

The semi-permanent Wolff tower cranes are positioned for their operating radii to overlap to facilitate segment ring delivery, sorting, storage and delivery down the shaft. The 30m crane is also required for changing locos, loco batteries and other heavy components up and down the shaft.

Safety and environment

Of course, all responsible construction

Left: At the Willesden Channel Gate Road drive shaft site Cat TBM 'Evelyn' is prepared for installation

Below: National Grid's UK Construction project manager John Trounson in the TBM back-up system





Left: Both Eade Road tower cranes seen from the main materials storage area

enter it. Even though most of the drives are in London Clay, bolted segmental lining was chosen for the 4-m tunnel in preference to the expanded lining normally found in London Clay drives due to the proximity of mixed soft ground.

There are currently six planned drives, including a spur to the UK Power Networks sub-station in Islington. Two will be driven from the Eade Road site to St John's Wood (9km) and Hackney (3km). Another, recently commenced, is being driven using the Caterpillar TBM from Willesden, through the Kensal Green sub-station shaft, to St John's Wood to join with the Herrenknecht drive. The Caterpillar TBM will then be transferred southwards to the drive shaft at Wandsworth, just south of the River Thames. From here it will first drive south to Wimbledon and then be returned to Wandsworth to drive under the River Thames, past a headhouse shaft at Earls Court, and onwards back to Kensal Green to the North. A third TBM is under

consideration for the Islington spur drive but a decision has not yet been made at the time of writing.

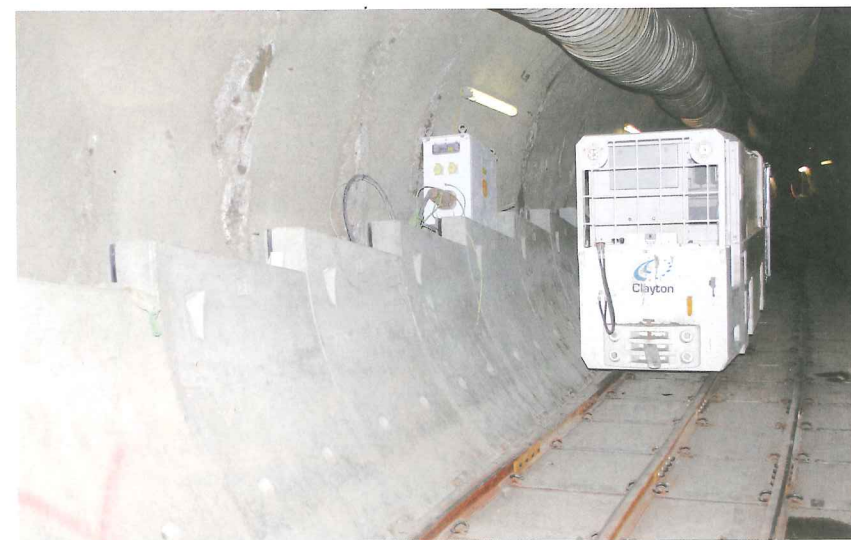
At the time of T&T's visit, eight shafts were complete and four more were under construction. All but two were due for completion by late March. Most shafts are constructed by conventional mechanical excavation with underpinned support lining rings. One was sunk by caisson and another required a diaphragm wall construction in less stable ground.

Stub tunnels or adits were excavated according to requirements about a year ago, especially for installing the TBMs. These were excavated by a Schaeff

banks men on entry to an Alimak hoist and at the shaft bottom. In the tunnel itself there are 'hop-up' platforms at 60m intervals as refuges from train operations.

Drives and shafts

All the drives in this development are either 4m or 3m in inside diameter and supported by Buchan precast trapezoidal (4-m) and wedge-block (3-m) segmental lining including Bekaert steel-fibre reinforcement. The ground is chiefly stiff London Clay although some of the alignment is close to the expected transition to the sand and gravel composing the Lambeth Group beds, and in one location is expected to



Right: Invert segments were installed in stub (adit) tunnels, previously lined with sprayed concrete, before the TBM got under way to facilitate track laying and moving the TBM forward

hydraulic mini-excavator and lined with sprayed concrete. The permanent linings may either be precast rings or cast in situ concrete, whichever is best suited.

The designs of both TBMs incorporate provision for the change of ground. The operational mode has not yet been decided for the second and third drives to be undertaken by the Caterpillar TBM as T&T goes to press, pending extra site investigation in the Earls Court area to determine the nature of the Lambeth Beds.

In addition to the lengthy drives there are a total of 14 shafts being sunk, reduced in number from the originally planned 16. Only three of these (Eade Road, Channel Gate Road and Wandsworth) are designated as drive shafts, but others give opportunities for TBM maintenance and serve purposes for the final construction.

Alternate shafts will be equipped with extraction fans in headhouses. Artificial ventilation will be necessary not only to facilitate inspections and maintenance in the long tunnels, but also to remove heat emanating from the cables.

At some shaft sites new sub-stations will be built, and the shaft on the Seven Sisters Road links with the UK Power Networks distributor sub-station. From Kensal Green the sub-station will supply power for the Crossrail trains. These will be the first sub-stations built by National Grid in the London area for 30 years.

Open and closed

In recognition of the risk of passing through permeable beds of sand and gravel, both

TBMs operate in a choice of semi-closed modes, although they are not expected to have to be converted to full EPB mode. At the present time the Herrenknecht TBM driving the 9km from Eade Road to St John's Wood and is operating in screw conveyor mode from the face invert so that apertures can be quickly closed off in case of the Lambeth Beds containing water being hit. It will then be returned to Eade Road for the 3km-drive to Hackney.

Conversely, the Caterpillar TBM starting its first drive is operating in open belt conveyor mode from the centre of the face since all the drive is expected to be well within the stiff London Clay.

So currently the choice is a matter of optimum spoil handling rather than face support on the TBMs. When in closed auger mode the rate of spoil extraction from the face can be better regulated by the screw conveyor, but it does not form a seal to hold face pressure as in full EPB.

Spoil

Whether carried from the TBM face by auger-screw conveyor or belt conveyor, spoil is loaded into cars, hauled by a 20t Clayton battery locomotive, within the TBM back-up train. At the shaft bottom each car is placed in a tippler for discharge into a hopper feeding a short belt conveyor that, in turn, feeds a vertical conveyor to carry the spoil up the shaft. At the shaft top the vertical conveyor discharges onto a high-angle belt conveyor (HAC) that lifts the spoil to a sufficient height to create a muck pile in the storage area. From this area a wheel

loader loads the spoil out to road-trucks waiting on the one-way site haul road.

Andy Frith, Costain construction manager, explained, "The target progress of up to 23 rings per shift will place high demands on the mucking out facilities, but we are set up for 25 rings. There is about 20m³ of solid ground to be excavated per ring, equivalent to 900m³ loose per shift. This will need 45 trucks a shift to remove from site, and therefore 90 trucks per day, but we do have 36h of storage to avoid night traffic."

Community relations

With all working sites in congested urban areas and most of the drives passing under residential areas, community/public relations were to play a major role in the project. Of course the project will benefit most Londoners but in the construction phase that might not always be obvious without an educational programme.

There are also major third-party matters to be considered. At the time of the visit the Eade Road TBM was passing under its first-major third party interaction – London Underground's Piccadilly Line.

One common event is a TBM naming competition with community schools. In the case of Eade Road, nine-year-old Tottenham Cub Scout Libby O'Shea who won a competition organised by National Grid named the Herrenknecht TBM 'Cleopatra'. The Caterpillar TBM was named 'Evelyn' by 9-year-old Chastity Nyadu-Bekoe of St Joseph's Primary School, Willesden. ▽

Project summary

Project:	London Power Tunnels Phase One
Owner and project management:	National Grid
Main contractor:	Costain
[in partnership with]:	Joseph Gallagher (tunnelling) VVB (site mechanical & electrics) Cementation Skanska (diaphragm walling)
Length of tunnels:	32km in five drives
Tunnel diameters:	4m i.d. by Herrenknecht TBM and 3m i.d. by Caterpillar TBM; both semi-closed face
Ground:	Mainly stiff London Clay with some cutting through Lambeth Beds of sands and gravels with low pressure groundwater expected



Above: View down the Eade Road shaft showing muck car tippler device, spoil hopper, and the net-enclosed vertical spoil conveyor

Mentoring with meaning

It can't be often that a Westpoint graduate finds themselves working on a tunnelling project, at least not in the UK. But to Linda Miller, with her globe-trotting background in which only the military can emulate engineering, it is probably nothing that unusual.

To one who has taken delight in blasting rocks from a US Army helicopter, the necessarily more careful activities in reconstructing the Connaught Tunnel in London's Docklands could seem a bit tame, even as project manager. But Miller seems to enjoy most types of challenge, approaching them with great enthusiasm, and the Connaught Tunnel certainly is a challenge. Here the original ideas for making this route useable for Crossrail have had, due to site circumstances, to be put in the waste-bin, and a new approach followed (see report in the next issue, *T&T* June 2012).

Linda Miller sees many similarities between military life and construction. One word that keeps cropping up in describing her career to date is 'meaning', often coupled with 'service', 'big toys', and 'laughing loudly' – all characteristics of working life that she enjoys in construction and the army before.

Miller gained her primary inspiration and most important career advice from her father, a military man. "He said, over and over again," recalls Miller, "It doesn't matter what you do as long as it is meaningful." So you can say I had a career that had meaning, even with the changes."

She enjoys the prospect of mentoring younger construction engineers and of passing on an understanding of the industry, and Crossrail activities in particular to local schoolchildren and students. "I love encouraging people in construction", she says. "I spend a lot of time going to schools and we (at Crossrail) plan to visit local primary schools to tell them what interesting things we are doing. I'm fully in favour of encouraging young people."

She was born in Fort Leavenworth, Kansas (not the federal penitentiary, but the

army camp, she hastens to add) and soon began travelling the world, as was common in military families. In this way she visited Italy, Germany and camps all over the US amongst other places, which Linda found an adventure. Following school she continued the military life by entering the Westpoint Military Academy, graduating as a lieutenant and with a degree in engineering – mainly mechanical but with some civil. This was quickly followed by a successful course to become a helicopter pilot, and so generating her love of 'big toys'. Globe-trotting again, she was posted to Korea and Germany, but still felt that her work had meaning and service.

"It's been my driving passion," Miller says with clear feeling. "I love being surrounded by robust, gutsy, loyal people, that hang together, and this has been so both in the army and in construction." She spent four years full-time flying and another six in the reserves.

"Eventually I decided to leave, but with a heavy heart, to try a new challenge," she explains. She went to the University of Berkeley, California, gaining a master's degree in mechanical engineering. She was not attracted by construction at first, but

she knew a man who worked for Bechtel who explained that it was 'just like the army' in many of the respects that she had enjoyed during her career.

In her new career in construction Linda Miller has worked on projects of all sizes, but with a tendency to the underground, including the Boston CA/T Project or 'Big Dig' for the I90.I93 highways in Boston, where she met her husband, and on preparatory designs for a new long monorail project in Seattle, which is now on 'hold'. Immediately prior to Crossrail her work was also in London, managing the Tubelines Underground renovation work on the Jubilee, Northern and Piccadilly Lines for Bechtel and Transport for London.

Linda Miller is married with two sons, who were adopted from northern Siberia. Her great grandparents were also Russian.

Now she seems to be settling in England after all the travelling, but with no less enthusiasm.

Back to mentoring and she says, "I say to young people, 'decide on the three or four things that will mark out a happy life for you, and stick with them.' I've found that big, difficult projects like Crossrail certainly help meet my criteria." ■



Above: Linda Miller on site for Crossrail contracts C310 Connaught Tunnel and C520 Custom House Station

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18 - 23 MAY 2012

World Tunnel Congress WTC 2012 & 38th General Assembly of the ITA, Bangkok, Thailand

'Tunnelling & Underground Space for a global Society', organised by the Thailand Underground & Tunnelling Group (TUTG) of the Engineering Institute of Thailand with the ITA, the theme is 'Tunnelling & Underground Space for a Global Society.' For more information email: secretariat@wtc2012.com or visit www.wtc2012.com

29 MAY - 01 JUNE 2012

SSCS - Numerical Modelling, Strategies for Sustainable Concrete Structures, Aix-en-Provence, France

Optimising the use of cement in concrete structures in view of CO₂ emissions. Organised by the Association Francaise de Genie Civil (AFGC). Contact Nadjet Berrahou-Daoud on tel.: +33 1 44 58 24 29, email afgc@enpc.fr or see www.sscs2012.com

30 MAY - 01 JUNE 2012

tc211-IS-GI - Recent Research, Advances & Execution Aspects of Ground Improvement, Crown Plaza La Palace, Brussels, Belgium

Intl symp & short course. Organised by Technical Committee 211 of the Belgian Building Research Institute with Comite Francais de Mechanique des Sols. For more info tel. +32 (0)2 655 77 11, email carina.godard@bbrl.be, or see www.bbrl.be.

24 - 27 JUNE 2012

North American Tunneling Conference (NAT), JW Marriott, Indianapolis, Indiana, USA

UCA's biannual conference, which has continued to grow each year with more exhibits, technical sessions & attendees. More information regarding housing and registration is available on <http://uca.smenet.org>, or email meetings@smenet.org, or tel.: +1 303-948-4200.

27-28 JUNE 2012

Safety of Life in Tunnels (SOLIT2) international conference, Scandic Hotel, Berlin, Germany

Organised by IFAB (Ingenieure für angewandte Brandschutzforschung GmbH) with support of the ITA Committee on Operational Safety of Underground Facilities. Proceedings in German & English including speakers from Fogtech, STUVA, Ruhr University Bochum, CETU and Eurotunnel. Contact IFAB in Rostock on tel.: +49-381-8115545, email contact@solit.info or see www.solit.info

27-29 JUNE 2012

Underground City Forum, Corinthia Hotel, St Petersburg, Russia

'Integrated Development of City's Underground Space' intl forum concentrating on the transition from indiscriminate construction to elaborate models for using underground space. Organised by the Tunnelling Association of Russia and other national bodies. For more info tel. +7 812 325 05 64/65, email info@undergroundcity-forum.com or see www.undergroundcity-forum.com

10-11 SEPTEMBER 2012

Baku Tunnelling Congress, Azerbaijan

'Tunnels & Underground Infrastructure of Urban Areas' including extension of metros and tunnels in Azerbaijan, Russia, Kazakhstan, etc. Full paper submission deadline 1 June. Organised by the Azerbaijan Tunneling Assoc with the French Tunneling and Underground Space Association (AFTES). For more info email baku.conference2012@azta-asso.com or view www.azta-asso.com.

18 - 21 SEPTEMBER 2012

'The Tunnel Connects' Eastern European Tunnelling Congress, Budapest, Hungary

The Hungarian Tunnelling Association is organising the 1st Eastern European Tunnelling Congress to share experiences and exchange knowledge of design, construction management, research results and technical developments of tunnels completed by the regional associations and experts. The planned regional sub-European conference is open to all other co-organizers and participants as well as to those who having ongoing or completed projects, research works in this area. More information at <http://www.eetc2012budapest.com> or contact Diamond Congress Ltd., tel.: +36 1 2250210 or email diamond@diamond-congress.hu.

8-10 OCTOBER 2012

Intermat Middle East, Abu Dhabi National Exhibition Centre

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17-20 OCTOBER 2012

Montreal TAC 2012, Canada

'Tunnels & Underground Spaces: Sustainability & Innovations: Sustainability & Innovations', organised by the Tunneling Association of Canada. For more info contact Wayne Gibson, conference manager, c/o Gibson Group Association Management, Richmond, BC, tel: +(604) 241-1297, email info@tac2012.ca or see www.tac2012.ca.

7 - 9 NOVEMBER 2012

13th World Conference of ACUUS, Marina Bay Sands, Singapore

ACUUS presents 'Underground Space Development - Opportunities and Challenges' to focus on new opportunities in developing underground space as sustainable development. More info from E-Quezt Concierge, Singapore tel.: +(65) 6271 2453, email info@acuu2012.com or see <http://www.acuu2012.com>

18-20 MARCH 2013

TU-Seoul 2013

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31 MAY - 7 JUNE 2013

WTC 2013, Geneva, Switzerland
World Tunnel Congress at International Conference Centre. Organised by Swiss Tunneling Society. For more information tel.: +41 (0)81 725 31 32, email sia-fgu@swisstunnel.ch or see www.wtc2013.ch

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17 MAY 2012

BTS AGM and the Brenner Base Tunnel

Konrad Bergmeister of BBT SE and the University of Natural Resources and Applied Life Sciences, Vienna, describes cross-border planning and implementation of 64km of tunnel route (200km in total) to connect Austria and Italy

14 JUNE 2012 (A WEEK EARLY)

Thames Water Lee Tunnel - London's Deepest and Largest

A presentation on the current status of the Lee Tunnel and Thames Tunnel for Thames Water's mega-sewer project by Roger Mitchell (CH2M Hill), Scott McFadden (Morgan Sindall), & Jean-Christophe Galan (Vinci Construction)

2-6 JULY 2012

BTS Tunnel Design & Construction Course, University of Warwick, England

In-depth introduction to the majority of tunnelling-related subjects, presented by industry experts. Ideal for young consulting and contracting engineering starting a career in tunnelling, and others (eg clients and insurance professionals) with an involvement in tunnelling.

20 SEPTEMBER 2012

Meeting subject and speaker to be confirmed

18 OCTOBER 2012

Tunnel Security and Blast Analysis

Blast protection design of transport tunnels. Speaker to be announced.

15 NOVEMBER 2012

EPBM & Slurry Tunnelling Principles

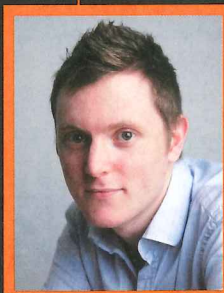
Safe operational protocols for full-face TBMs. Speaker to be announced.

20 DECEMBER 2012

Debate: 'This house believes tunnel projects in the UK are over-staffed and over-specified'

Speakers to be announced.

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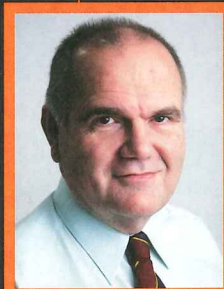
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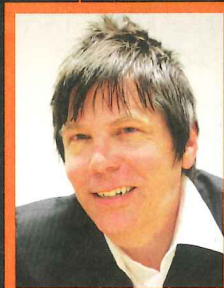
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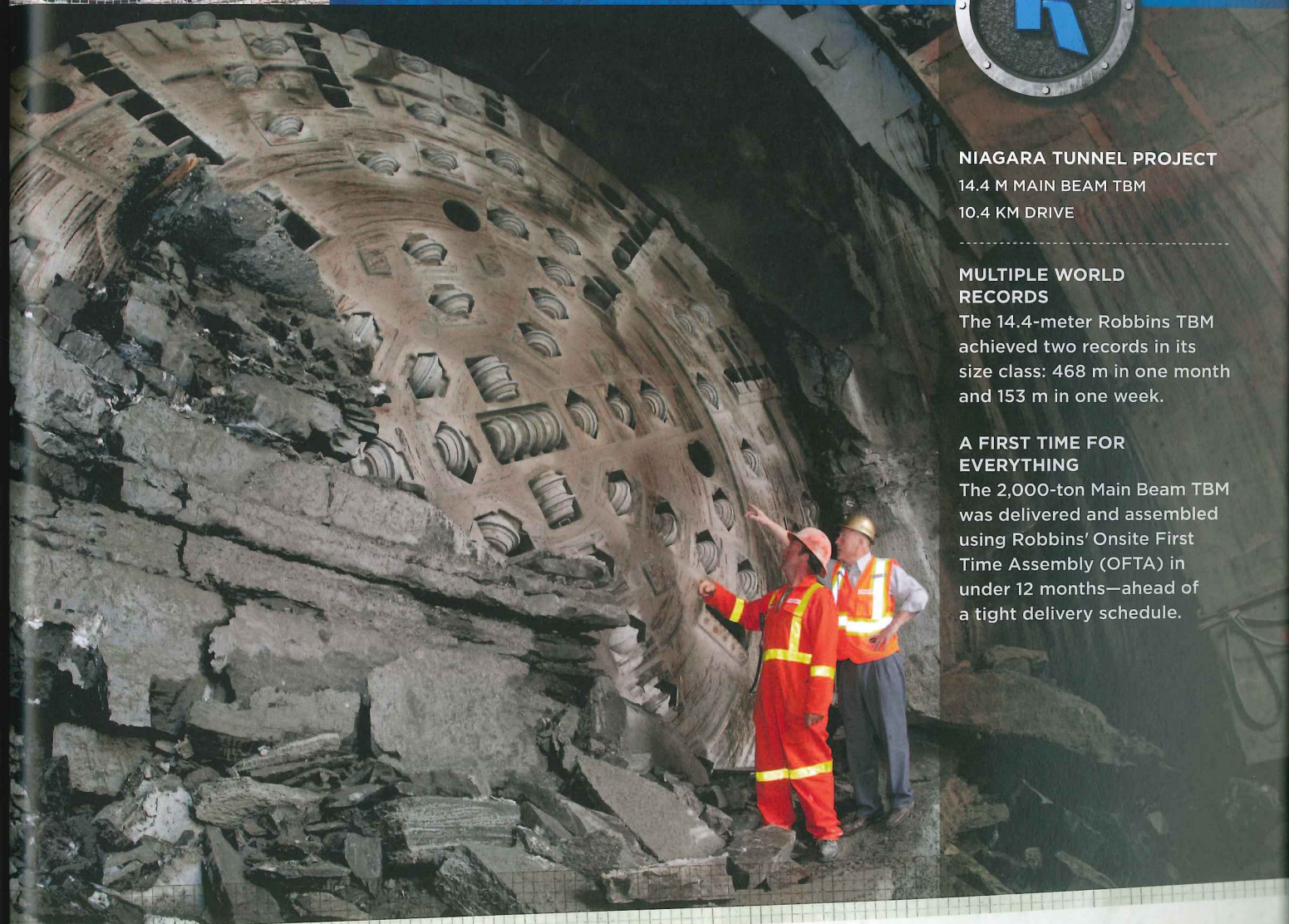
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