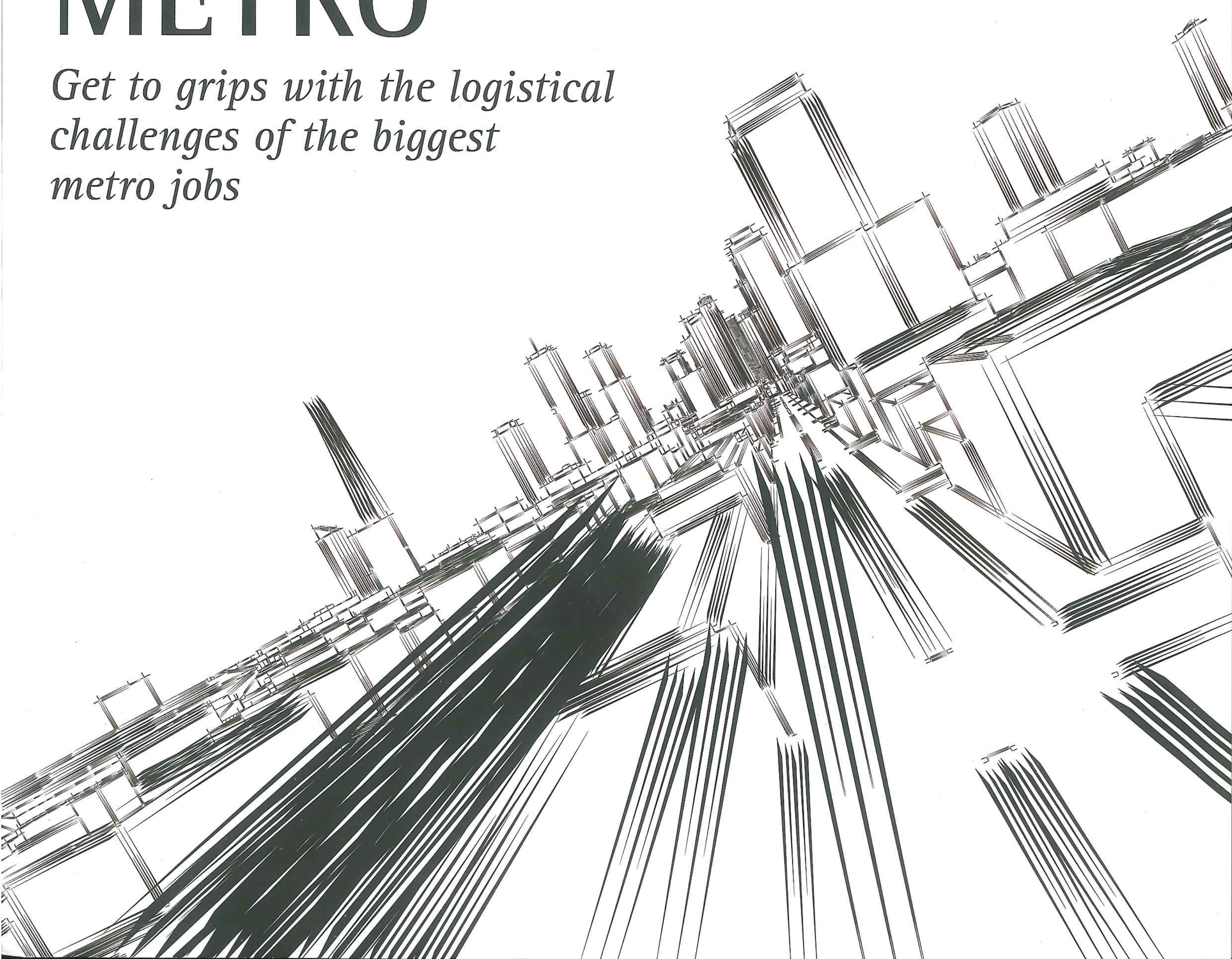
Tunnels
AND TUNNELLING

MASSIVE METRO

Get to grips with the logistical challenges of the biggest metro jobs



DOWN AND OUT: CATERPILLAR TUNNELLING

THERE IS no escaping the big story this month. The company that was going to change the way we buy TBMs and ultimately the way we design tunnels has abandoned the industry. Caterpillar last month announced the closure of it's Toronto-based TBM manufacturing business Caterpillar Tunnelling Coporation Canada (CTCC) and exited the TBM market.

Caterpillar bought manufacturer Lovat for CAD 49M in 2008 and was much rumored to have plans to standardize and mass produce TBMs. The vision was to take the Caterpillar model of assembly line style machine production, with a catalogue of machines, many shared components and large numbers of order. Leaving aside the mega projects, Caterpillars method was aimed at cutting costs and dominating the medium bore market.

However, in an industry accustomed to bespoke equipment the idea was not well received.

While investing some CAD 50M in factory expansions and the purchase of machinery (greatly increasing the plants capacity) the company reinvented its approach. Custom-built TBMs were back on the cards. The guts of the machines were largely standardized but the package was set to meet the demands one project at a time. It made improvements to the offering too, such as remolding the cutting tools so that rippers, for example, would be made out of a single piece of metal, prolonging its wear life.

Caterpillar had bought one of the pioneering firms in TBM technology. With a 40 year history in the industry, Lovat had built a reputation for robust medium diameter EBPs and had built up a strong export business tunnelling in London, Hong Kong, Singapore, Beijing and large amount in Russia. The company produced more than 250 TBMs and excavated more than 2,500km of tunnel on some 700 tunnelling projects.

But last month Caterpillar decided to walk away. The big projects in Toronto (Spadina, LRT) that flooded Lovat's order books and drove a need for growth have dried up. The 330 people at the plant are being put out of work. The company will cease operations next year and end support and parts in 2016.

The business has taken such a turn for the worse that Caterpillar believes there is no resale option. After paying some CAD 50M for Lovat and investing the same again in factory developments the company is shutting up shop.

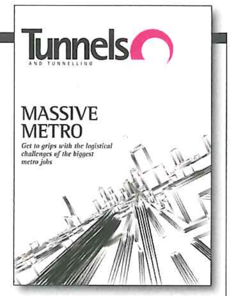
The news was announced to staff on 2 May and hours later it was announced publically. The headquarters and machine factory on the corner of Disco Road and Carlingview Drive were quickly picketed by journalists.

The one employee arriving at lunchtime having missed the morning meeting was told of the company's fate by local reporters, he said "Oh well. I can't do anything about it. I don't let this stuff (bother me)," and he went home to look for another job.

Expect to hear more on this

Jon Young
Editor

Cover
This issue has an insight into the massive metros that drive the majority of new tunnelling demand globally



Next issue
In the July issue of *Tunnels* we focus on the North American tunnelling market, while industry experts weigh in with their thinking in a technical review of current active fire suppression. The tricky issue of the final disposal of nuclear waste is also tackled

This month...

10 YEARS AGO
Tunnelling began last month on contract CW-BID1 as part of the 98km-long Kunming Zhangjiuhe River water diversion and water supply project in southwest China. The contract includes the 7.8km-long Kangle tunnel and the 13.8km-long Shanggongshan tunnel.

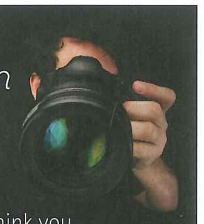
20 YEARS AGO
The problem-plagued Boston outfall tunnel is at last coming to life, with progress rates climbing after a difficult start, but more of the conditions which have caused many of the problems still lie ahead. The project faced public concern about sea pollution, a contractor challenged a union labour/no strike deal which escalated into a supreme court bid, and the drive hit heavily fissured argillite formations. This was before water infiltration of 1,600 gallons per minute became a problem, and a 480V electrical fire began. Delay and cost resolution led to further concerns. However, the project is still on schedule for completion in December 1994.

40 YEARS AGO
G. P. Giacobino presents "a patented method of excavating tunnels in soft ground by reinforcing the ground with a set of needles, thereby consolidating the ground".

This issue

Tottenham Court Road Station in London

Photo Competition



Don't forget to enter the Tunnels and Tunnelling Photo Competition if you think you have what it takes to claim the latest in digital camera technology as your prize.
The closing date for entries is 1 September and the short listed entrants will be announced in the October issue. The winners will be announced in the Tunnels Awards supplement in the December issue of *Tunnels*.
awards@tunnelsonline.info

Contributors

Ermin Stehlik
Ermin is a tunnelling specialist for Czech contractor Metrostav. He works extensively for *Tunnels*

Desiree Willis
Desiree has worked for TBM manufacturer Robbins for nearly a decade as a technical writer

Andreas Feiersinger
Andreas works in the London offices of Dr. Sauer & Partners, and currently works on TCRSU

CATERPILLAR TO ABANDON TUNNELS

Canada Caterpillar Tunneling Canada Corporation (CTCC) revealed last month that it will exit the tunnelling business and cease all production by mid 2014. The company was created following Caterpillar's purchase of Lovat in 2008. Caterpillar said the enterprise no longer represented a "strategic growth opportunity".

The company said it will honour contractual obligations to customers including after sales support, and would provide parts and service support up to 2016. Its 330 employees are receiving a severance package.

Stu Levenick, Caterpillar group president said: "We continuously evaluate our strategic portfolio to ensure alignment with our long-term strategy and have concluded the tunneling business no longer fits that strategy.

"As a result, we have elected to exit the business. We know this is difficult news for our employees and their families. We acquired a great team when we bought this company, and while they have demonstrated an ability to build quality products, the future prospects of this business no longer align with our expectations."

Tunnels understands that Caterpillar invested some CAD 50M (USD 49.6M) into its production facility in Toronto.

OSHA issues final rule to protect underground construction workers

USA The US-based Occupational Safety and Health Administration (OSHA) has issues a final ruling to protect workers using cranes and derricks in demolition and underground construction, the Labor Department announced last month. Application of this rule will protect workers from hazards associated with hoisting equipment used during construction activities.

This final rule applies the same crane rules to underground construction and demolition that are already being used by other construction sectors, and streamlines OSHA's standards by eliminating the separate cranes and derricks standard currently used for underground and demolition work. The rule also corrects errors made to the underground construction and demolition standards in the 2010 rulemaking. The final rule became effective 23 May 2013.

Norway plans world's first shipping tunnel

Norway The Norwegian government has announced plans to build a ship tunnel through a mountain to cut out a section of treacherous water on its southwest coast.

Unveiling a 10-year transportation plan, the government said it would earmark 1bn kroner (USD 266M) for the construction of the Stad maritime tunnel, named for the peninsula notorious for high winds and heavy seas.

The tunnel has a planned height of 49m, width of 36m, and length of 1.8km. Construction is expected to begin in 2018 and take four years. If the project goes ahead, it will be the world's first shipping tunnel capable of handling large vessels.

Blasting concludes under NY's Grand Central Terminal

USA Sandhogs working on the East Side Access project have concluded blasting under Grand Central Terminal, where they are building two caverns 160ft (49m) below street level that will house eight tracks for Long Island Rail Road trains, the Metropolitan Transportation Authority (MTA) announced last month.

Since March 2007, nearly 1,000 employees working 24 hours a day, five days a week, have completed more than 2,400 controlled blasts ¬ all without affecting the nearby operations of MTA Metro-North Railroad or the New York City Subway, the authority stated.

"This is a very significant milestone for the East Side Access project, said Michael Horodniceanu, president of MTA Capital Construction. "The caverns are essentially now fully excavated. Much work remains to be done to build the platforms and tracks, and finish what is currently raw, cave-like space. But we now have a fully built shell in which all future work will take place."

The contractors, a joint venture of Dragados USA and Judlau Contracting, are continuing to perform miscellaneous concrete work until their contract is complete in June. They expect that they may need to make additional small blasts that will trim out pieces of rock in the cavern.

Top candidate named for Californian bullet train project

USA The California High-Speed Rail Authority has named the top candidate for the first part of the 500 miles (805km) high-speed rail line between Los Angeles and San Francisco. The top candidate to build the 29 miles (47km) of California's bullet train in the Central Valley bid just under USD 1bn, below the state estimate of the cost, project officials announced.

The authority said Tutor Perini/Zachry/Parsons, a joint venture of US firms, submitted a bid of some USD 985M and was ranked first out of five competitors. The team offered the apparent best value based on price and technical proposals, evaluators stated.

The five teams submitted their proposals in January, which were evaluated by a panel of state officials.

Rail officials had estimated the cost of the initial section between Madera and Fresno at USD 1.2bn to USD 1.8bn. Construction is expected to begin by July.

The high-speed rail board is expected to award the contract for the first section in the coming weeks.

The train line will carry some trains at speeds faster than 200mph (322mpk). It is now estimated to cost at least USD 68bn, the fourth revision over the years.

Finland considers longest undersea tunnel

Finland A survey from Finnish geology centre, GTK, are going to prepare a study for possible future routes for a rail tunnel to connect Helsinki and Tallinn, Estonian newspaper Eesti Päevaleht reported.

The tunnel's length would depend upon the route taken; the shortest distance across would have a submarine length of 50km, making it the longest undersea tunnel in the world.

The Estonian geology centre has already prepared a study about the route selection, which was commissioned by the Finnish authorities that cost tens of thousands of Euros.

According to calculations, the tunnel project would cost between EUR 2bn to 3bn (USD 2.6bn to 3.9bn) and construction works could start in 2050.

MAJOR CROSSRAIL WORKS UNDERWAY AT VICTORIAN CONNAUGHT TUNNEL

Great Britain A hole has been drilled in the exposed crown of the Connaught Tunnel, which runs beneath the Royal Victoria Dock, following work to drain 13 million litres of water from a section of the docks that lie above, said a spokesman for metro project Crossrail.

Work will now continue to open up a hole that will eventually measure some 20m long and 10m wide. This will give access to strengthen, deepen and widen the central section of the tunnel so that it can accommodate Crossrail's trains. Work will also include waterproofing, installing water pumps and cleaning the 135 years of coal and soot from the bricks. (*Tunnels*, June 2011, p.22)

Sections of the tunnel are in a poor condition and parts of it were narrowed during the 1930s so that the dock could be deepened to accommodate larger ships with brickwork removed and steel segments installed.

Work is ongoing to refurbish the Connaught tunnel for inclusion in the Crossrail scheme

The hole in the crown of the tunnel will allow Crossrail to remove much of this material and to continue with the process of ensuring that the tunnel is safe and ready for the arrival of the new trains upon project commissioning in 2018.

Over the last few months a cofferdam measuring 1300sqm has been put in place to allow a section of the Royal Victoria Dock to be drained so that workers can access the tunnel from above.

The tunnel was built in 1878 and has not been in passenger use since December 2006. It is the only existing tunnel that will be re-used for Crossrail.

Linda Miller, Connaught Tunnel project manager, said: "The Connaught Tunnel is testament to the engineering skill of the Victorians, but after 135 years there's a lot of work that needs to be done to get it ready for Crossrail.

"Now we've opened the top of the tunnel we'll start the engineering equivalent of open heart surgery; widening and deepening the structure so that it can accommodate up to twelve trains an hour in each direction."

Thai government plans massive rail investment

Thailand The Mass Rapid Transit Authority (MRTA) of Thailand and State Railway of Thailand (SRT) are tasked with implementing multiple rail and mass-transit projects under the THB 2tn (USD 68bn) state borrowing programme. The government is awaiting parliamentary approval for its proposed legislation to borrow the massive amount.

According to Yongsit Rojsrikul, governor of the MRTA, his agency alone is responsible for eight elevated-train and subway projects in Bangkok and peripherals under the programme. "The Purple Line of 23km from Bang Yai to Bang Sue is under construction," Yongsit said. "It's now 50 per cent completed. Another project, the extended Blue Line, which is more than 20km long, is also under construction. The third project under way is the south Green Line, which is 17km long, from Bearing to Samut Prakan.

"Additional projects under the THB 2tn funding scheme include the north Green Line's 17km extension from Mor Chit to Kukot and the Pink Line from Khae Rai to Min Buri (34km). Bidding for construction contracts will take place this year.

"Next year, we will invite bids for the Orange Line, starting from the cultural centre in Huai Khwang to Min Buri, totalling about 20km. The borrowing scheme also covers the Yellow Line from Lat Phrao to Samrong, totalling 30km.

"Altogether, eight projects for a total of six lines will be financed by this borrowing scheme, with funding estimated to be in excess of THB 400bn (USD 13.76bn) for implementation over the next six to seven years. Overall, we're responsible for 230km of elevated railway and subway."

Prapat Chongsanguan, governor of SRT, said: "We're also responsible for part of Bangkok's suburban train project under the Red Line from Taling Chan to Rangsit totalling 30km. We signed the first and second construction contracts last month. It will take four years to complete.

"Additionally, we will further extend the Airport Link from Makkasan to Don Mueang Airport."

Additionally, as part of the investment, Thailand will be building 1,300km of HSR.

Hammersmith A4 tunnel could replace flyover

Great Britain London architects who call Hammersmith Flyover a 'terrible act of vandalism' have proposed replacing it with an underpass. Hammersmith and Fulham Council said that it supports the plan following concerns about the flyover's long term cost and viability. It invited residents to comment online.

Czech capital hosts successful event and calls for new line

Czech Republic Underground Construction Prague was held last month. The event was well attended, falling close to the 40th operational anniversary of the Czech capital's metro, which falls next year. Ermin Stehlik of local contractor Metrostav gave a keynote presentation on the metro's history, the third and final part of which is published on page 21.

On every Czech's mind however was the future of the network. The proposed Line D is at risk from political indecision, and the amount of underground work in the country is not limitless.

The case for the new line is seen in the current annual ridership figures, claimed to be around half of that experienced by the London Underground, but with one eigth of the network length.

DC Water awards Anacostia River Tunnel

USA DC Water's board of directors recently approved the design and construction of the second portion of the tunnel system that will bring relief from combined sewer overflows (CSOs) to the Anacostia River.

The design builder of the USD 253.9M proposed contract is a JV of Impregilo-Healy-Parsons.

The tunnel will be approximately 12,500ft (3,840m) long, 23ft (7m) in diameter, and supported by a bolted, gasketed, one-pass lining system. The work will include six 90ft to 100ft (30m) deep shafts ranging from 12ft (3.6m) to 75ft (23m) in diameter. Three Adit connections are also required between the tunnel and three of the shafts; these adits will be between 4ft (1.2m) and 10ft (3m) in diameter.

"This decision by the Board of Directors sets in motion a very significant portion of the Clean Rivers Project," said DC Water board chairman Allen Y. Lew. "This metro-sized tunnel will store combined-sewer runoff during intense rainstorms to prevent CSOs to the Anacostia River, improving the health of this important District waterway."

Undersea tunnel to link West Bay with Doha airport

Qatar A project is underway to link the West Bay area with the Hamad International Airport (HIA) through an undersea tunnel. This will be one of the major projects to be implemented in the coming years linking Doha south, central Doha and Doha north.

The project will start from West Bay near the City Center as a two-lane bridge in both directions towards the sea and then become a tunnel under the sea leading to the airport. It will meet a second subway starting from the new airport road with a three-lane undersea tunnel leading to New Doha.

The third segment of the project starts from Lusail with three lanes in each direction, with a bridge and undersea tunnel leading to New Doha. All these lanes will join at one point under the sea off the Corniche.

MILESTONE BREAKTHROUGH FOR MALAYSIAN WATER TUNNEL

Malaysia The first of three 5.23m main beam Robbins TBMs broke through at the Pahang Selangor Raw Water Tunnel at the end of March, the manufacturer announced last month. The breakthrough is a significant step towards the completion of the longest tunnel in Southeast Asia, a 44.6km water transfer route from the states of Pahang to Selangor.

"Many challenges were overcome by the TBM and its continuous conveyor system on the 11km run, including blocky rock, over-break, power outages, extremely high rock temperature and water inflows," explained a Robbins spokesman. Field service teams worked closely with the contractor, a joint venture of Shimizu Corporation, Nishimatsu Construction, UEM Builders, and IJM Construction (SNUI). Despite the variable conditions, the TBM maintained strong advance rates of 475m per month on average.

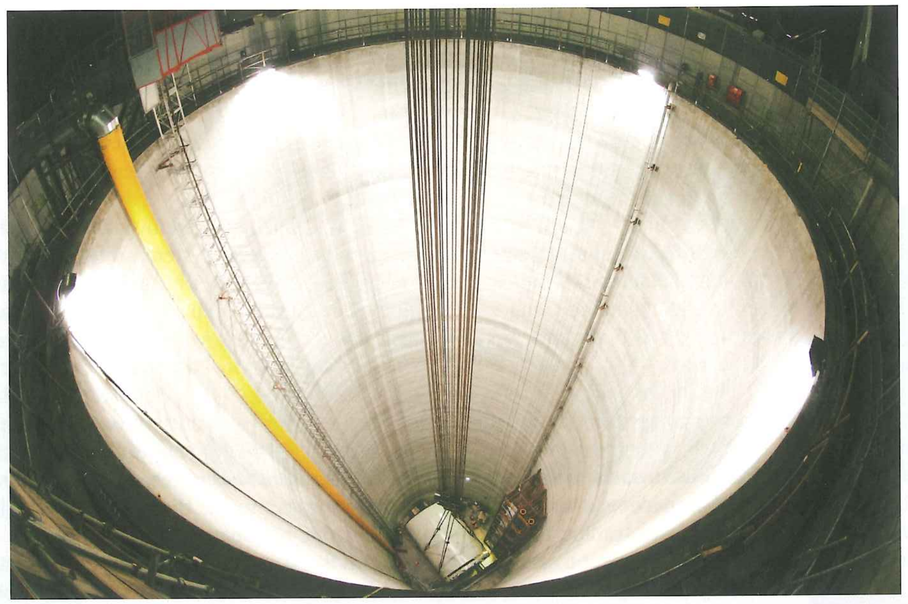
Various methods of support were used during boring, the primary being near-zero rebound fiber mortar. The Pahang Selangor project marks the first time that this method has been used outside of Japan.

"This is a day we all look forward to in the tunneling industry," said Andy Birch, field service manager, Robbins. "It's a good feeling when you get through all of the hard work and eventually break through. I'm very happy for this joint venture, and they seem very happy too."

The two remaining 5.23m machines are currently boring respective 11km runs, and are on schedule to meet inside the tunnel in autumn 2013. Upon completion, the tunnel will transfer 27.6cu.m of water per second to a new treatment plant.

The drinking water will supply about 7.2 million people for project owner KeTTHA (Malaysian Ministry of Energy, Green Technology, and Water).

The centre of Doha, where the undersea tunnel will link to the city's airport



IN MURKY WATERS...

I was most interested to read your 'Editor's Comment' article in the May edition regarding Margaret Thatcher's contribution in inspiring the construction of the Channel Tunnel.

You have rightly said that her vision was a driving force behind the building of the Channel Tunnel. I believe without her enthusiasm the project would not have got off the ground. However I would like to give a different perspective to some of your other comments.

Firstly regarding overruns on cost.

It is not correct to say that the costs over ran by 100 per cent. The over run was in fact from an original estimate of GBP 6.5bn to an out turn cost of GBP 10.6bn i.e. 63 per cent. Now this is, of course, a very large increase but in judging this increase and using it to make a general judgement about large infrastructure projects would be a mistake. Let me clarify this:

- A long sub aqueous tunnel of this length had never been attempted before and therefore some of the costs were bound to have an uncertainty factor
- Yes, there was no doubt a certain optimism applied to the estimates in order to get the project off the ground. All those involved including funding banks and the Channel Tunnel Group and France Manche, were no doubt party to this sense of optimism
- A major factor was the fact that the project was built on a 'fast track' basis i.e. the design was not complete when construction commenced and at times was only just coming off the drawing board in order to allow construction to go ahead. For this reason a number of items that came out of this design were not and could not have been allowed in the original costings. As an example of this it was not realised when construction commenced that the double engines to haul the shuttle trains would absorb 11.4MW of power. Calculations showed that this would cause a progressive heating up of the tunnel surrounds resulting in an ever increasing and unacceptable environment in the tunnel. Therefore an extremely expensive cooling system was introduced into the tunnel. My memory says this cost in excess of GBP 100M extra. In addition we had a dedicated Safety Authority that was appointed by the two governments to oversee safety, and of course the two sides of the Safety Authority never agreed with each other. The result was a number of unreasonable decisions against which we could not appeal. For example the authority had approved the design of the passenger shuttle cars and manufacturing was well ahead when it suddenly changed its mind about the width of the passenger doors. This again caused extra costs of well into the tens of millions.
- Inevitably there were claims from contractor TML. A major one was the presence of unexpected water in the tunnel face when the service tunnel, which was the pilot tunnel, encountered this water 4km off the UK shore. This caused a lot of delays and also resulted in the two running tunnels having to be extensively grouted in advance of the TBMs. This grouting being done from the service tunnel. This was an extremely expensive operation and caused considerable delay to tunnelling

Second, the method of funding. This was from 250 banks with five lead banks. It was hoped to raise GBP 1bn in equity and GBP 5.5bn in loans. The only problem was that the two governments refused to give any guarantees for the loans. The result of this politicking was that the loans were given with a 12 per cent interest rate. You don't have to be good at maths to realise that there could never have been enough traffic to make the necessary repayments. I went on to Storebaelt in Denmark where the Danish government guaranteed the loans, resulting in an interest rate of 6 per cent. The rest is history, the loans were 'rationalised', in other words loan money was swapped for equity. So one has to assume that the banks largely own the project. It is relevant to note that for the financial year 2011 Eurotunnel made a trading profit of EUR 272M and after the interest on the residual loan had been paid a net profit of EUR 11M. Oh to be a banker!

Alastair Biggart, Tunnelling LLP

News briefs

USA

A superior court awarded King County, Washington, USD 14.7M in legal fees last month in a dispute over a tunneling project for the Brightwater sewage-treatment plant in Woodinville, local press reported.

King County filed the lawsuit against VPFK in 2010 with claims that contractors failed to meet deadlines after two TBMs broke down hundreds of feet into the ground. VPFK – a joint venture of Vinci Construction Grands Projets, Parsons, and Frontier-Kemper Constructors – had been given a USD 212M contract to bore two Brightwater tunnels after a bidding process in 2006.

USA

The first TBM, Mom Chung, for the southbound tunnel of San Francisco's USD 233.5M Central Subway tunneling contract, has arrived on site.

The machine is one of two TBMs built for the project. This month Mom Chung will start excavating the southbound tunnel, digging at a rate of about 40ft (12m) per day. Sister TBM Big Alma will begin building the tunnel for northbound trains about two months later.

USA

The Metropolitan St Louis Sewer District has awarded a contract to Parsons Brinckerhoff, as a subconsultant to Shannon and Wilson for construction management services for the Lower and Middle River Des Peres tunnel programme, the company announced earlier this month.

Contact us

Send us your opinions: *editor@tunnelsonline.info*
7 Carmelite Street, London, EC4Y 0BS

Central bank rates

	Rate (%)
AUD	2.75
BRL	7.25
CAD	1.00
CHF	0.25
CNY	6.00
EUR	0.50
GBP	0.50
INR	7.25
JPY	0.10
NZD	2.50
USD	0.25

Rates are taken on the 12th of each month.

Share tracker

Company	March	April	Change (%)
Aecom (NYSE: ACM)	31.41	30.69	▼ 0.72 (2.29)
Atkins (LSE: ATK)	913.00	912.5	▼ 0.5 (0.05)
Balfour Beatty (LSE: BBY)	272.00	250.2	▼ 21.8 (8.01)
BASF Global (XETRA: BAS)	73.36	68.4	▼ 4.96 (6.76)
Bekaert (BSE: BEKB)	22.54	22.5	▼ 0.04 (0.18)
Bilfinger Berger (DUS: GBF)	81.62		▲ 5.05 (6.58)
Caterpillar (NYSE: CAT)	89.74	85.05	▼ 4.69 (5.23)
Costain Group (LSE: COST)	289.56	291.75	▲ 2.19 (0.76)
Ferrovial (MCE: FER)	12.56		▲ 1.28 (11.31)
Hindustan Construction Company (BOM: HCC)	15.50	14.15	▼ 1.35 (8.71)
Hochtief (XETRA: HOT)	55.09	50.71	▼ 4.38 (7.95)
Morgan Sindall (LSE: MGNS)	542.50	552	▲ 9.5 (1.75)
Sandvik (STO: SAND)	104.70	97.75	▼ 6.95 (6.64)
Shanghai Tunnel Engineering (SHA: 600820)	8.88	9.06	▲ 0.18 (2.03)
Strabag (LSE: STR)	18.65	16.73	▼ 1.92 (10.29)
URS Corporation (NYSE: URS)	45.09	46.32	▲ 1.23 (2.73)
Vinci (EPA: DG)	36.49	35.86	▼ 0.63 (1.73)

Prices are taken on the 12th of each month. NYSE is in USD. LSE is in GBP. STO is in SEK. BSE, EPA, MCE, STR and XETRA are in EUR. BOM is in INR. SHA is in CNY.

Strabag CEO resigns

Austria Dr Hans Peter Haselsteiner, the chief executive officer of Strabag, resigned from the company at a meeting with the supervisory board late last month. Haselsteiner's resignation is effective with the end of of the 2013 Annual General Meeting on 14 June this year.

It is Haselsteiner's intention to continue to support the management board as an authorised representative in matters concerning the group's internationalisation and strategic orientation, the company stated. After discussion, the supervisory board accepted his resignation.

Dr Thomas Birtel, deputy CEO, was appointed as new CEO by the supervisory board at the same meeting.

Dr Alfred Gusenbauer, chairman of the Strabag supervisory board, said: "On behalf of all employees and the supervisory board, I am grateful that Hans Peter Haselsteiner will remain with the company in another function.

"We believe that Thomas Birtel, who has been with the group for nearly twenty years, is perfectly prepared to continue to successfully shape STRABAG's future."

Crossrail announces operations director and star apprentices

Brazil Global engineering firm, Mott MacDonald, is acquiring Habtec Engenharia Ambienta, a Brazilian environmental engineering consultancy firm, a Mott MacDonald spokesman announced in the middle of April 2013.

Mott MacDonald stated that the acquisition is part of the company's strategy to create a regional base in Brazil from where it can expand across South America.

Mott MacDonald's association with Brazil goes back 40 years. Its portfolio includes Rodoanel highway Sao Paulo Concession, Pernambuco power project, Sao Paulo and Rio de Janeiro metros, the Rio-Niteroi bridge and the Campinas to Mogi Mirim highway.

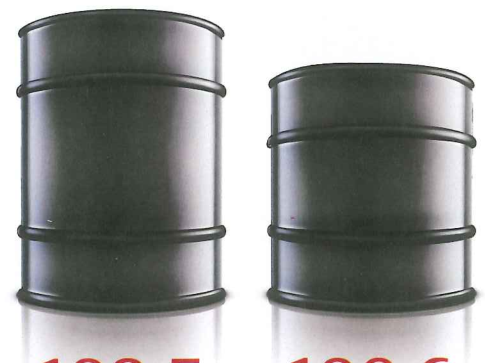
Most recently, Mott MacDonald has worked on energy, transport, health, education and environment projects in Brazil.

Habtec has been operating principally in the energy, mining and transport sectors for over 20 years. Employing about 80 people, the company's project portfolio includes various environmental impact reporting studies, compliance support, monitoring of projects and environmental education programs for Petrobras, BG Brasil, Shell, Vale, Furnas, Repsol Sinopec, and OGX.

"Habtec has an excellent reputation and shares the same values and has a similar culture to Mott MacDonald," said Keith Howells, Mott MacDonald's chairman.

He added, "Bringing Habtec into the group will allow the development and growth of what is already a highly regarded team and will give us a base in Brazil from which to offer the full range of Mott MacDonald's services."

Oil price



108.5 March 2013

100.6 April 2013

Values are taken on 12th of each month.

The tunnels will pass under the vital freight artery

NEW TUNNELS UNDER SUEZ

Three new tunnels will be built under the Suez Canal. The Egyptian government previously announced plans to create the tunnels, and according to local press Spain-based Getinsa Paymacotas has been contracted to carry out technical studies and prepare tender documents for the National Authority for Tunnels.

Two tunnels will reportedly be for roads and run for 3km, with one tunnel for rail at 5km. Each will be of 12.2m diameter.

At present only one road tunnel has been constructed beneath the canal north of Suez, the Martyr Ahmed Hamdi tunnel. The future tunnels will form part of the North Sinai industrial expansion and will also complete a coastal road development that will link Rafah and Nuweiba

NEW DAWN

Indonesia is an often overlooked Asian giant, yet it has all the potential to become an economic powerhouse, albeit one currently with poor infrastructure. This is a match made in heaven for tunnel work as the country enters an age of urbanisation and infrastructure investment. It was this year's Bauma partner country. **Danny Richards** of *Timetric*, the market analysis arm of *Tunnels* publisher presents this report

Danny Richards
Danny is a senior economist at Timetric and has presented in the past on India and other markets. This information was also on display at Bauma

IDONESIA, A sprawling archipelago of around 1.9 million square kilometres and with a population of some 245 million people, is increasingly being considered alongside the BRICs (Brazil, Russia, India, China) as an emerging market with the potential to be a major global economic heavyweight in the coming decades.

The country's well-balanced economy has been recording solid rates of growth in recent years, averaging over six per cent, and it came through the global financial crisis relatively unscathed. Foreign investment is also growing rapidly, and policymakers are keenly focused on boosting economic growth.

However, there are risks. Indonesia's infrastructure is underdeveloped and in need of massive investment. Although the government has set an ambitious plan to address this issue, the required improvements to transport links, energy, and communications will take time.

There have also been worrying signs of growing nationalism in government policy, particularly regarding the regulatory environment for the mining sector, and this is undermining confidence. Nevertheless, there is no denying Indonesia's huge potential for growth, not only in exploiting its vast reserves of national resources, but also in construction, particularly in developing the country's infrastructure.

THICK SKINNED

Indonesia's economy bounced back strongly after the disastrous impact of the Asian financial crisis in the late 1990s, during which the economy shrank by 13 per cent in real terms. In the following 10-year period, Indonesia's nominal GDP increased from USD 235bn to USD 1.1tn, and per capita GDP soared from around USD 880 to USD 3,600. It is mainly owing to the fact that Indonesia has a relatively large domestic economy and a lower reliance on external trade than its Southeast Asian counterparts that it managed to continue posting healthy growth in 2009, while others such as Thailand and Malaysia experienced economic recessions amid the worst of the global financial crisis.

timetric

Market analysis and data by Timetric, part of Tunnels publisher WMI

FUNDING CONTROLLED, BUT NOT UNAVAILABLE

The Indonesian government has maintained a prudent fiscal policy stance in recent years, which, along with a well crafted monetary policy, has put the economy into strong and stable growth.

The government has succeeded in consistently maintaining the deficit below three per cent of GDP over the past 10 years. It has also managed to reduce its debt burden from a peak of 77 per cent of GDP in 2001 to just 24 per cent in 2012. Interest payments, which peaked to about 5.3 per cent of GDP in 2001, have also gradually been brought down, to just over one per cent of GDP in 2011, giving the government much needed room for reallocating resources for development purposes

Based on the recently approved budget estimates provided by the Ministry of Finance, government revenue is expected to grow by 11 per cent in

Table 1. Economic snapshot for Indonesia 2012

Attribute	Value
Population	245 million
GDP (nominal)	USD 910bn
GDP growth	6.2 per cent
Exchange rate	IDR 9,380 (USD 1)
Inflation	4.5 per cent
World Bank 'Doing Business' rank	128th (out of 185 countries)

Source: Timetric

2013, compared to 16.1 per cent in 2012. Income tax is projected to grow at a slower pace of 11.8 per cent in 2013, from 18.9 per cent estimated in 2012.

On the expenditure front, the government projects that its overall outlays in 2013 will grow by 7.1 per cent, slowing from an increase of 17.2 per cent in 2012. Capital expenditure is expected to grow by 15 per cent on the back of planned infrastructure development. Despite this expansion, the government is targeting a budget deficit equivalent to 1.7 per cent of GDP in 2013. It is partly owing to the improvement in the government's fiscal health that international credit ratings agencies have upgraded Indonesia's sovereign credit ratings. The rupiah, however, has shown itself to be volatile, losing seven per cent of its value against the US dollar in 2012. It is one of the worst performing currencies in Asia.

CONSTRUCTION SECTOR

Indonesia's construction sector has been performing well in recent years driven by strong economic activity and high levels of investment. Indeed, fixed investment has soared over the past decade, with its share of total GDP rising from 19.5 per cent in 2003 to a historic high of 33.2 per cent in 2012.

The construction sector has been a clear beneficiary of this investment activity. It has grown by 7.4 per cent on an average basis in real terms over the past 10 years, well above the GDP growth rate of 5.9 per cent. It maintained this rate of growth in 2012, expanding by 7.5 per cent. In line with this trend, the construction sector's share of total GDP increased from 6.2 per cent in 2003 to 10.4 per cent in 2012.

Despite some challenges, the outlook for construction is favorable. In nominal output value terms, the sector will grow by 15 per cent a year in the next five years, supported by urbanisation, rising incomes and the government's effort to improve the infrastructure base as part of its ambitious multiyear plan – the Master Plan for the Acceleration and Expansion of Indonesia's Economic Development. In order to attract investment for the master plan, which envisages spending of up to IDR 4,000tn (USD 400bn) during the 2011-2025 timeframe, the government is taking steps to strengthen public-private partnership regulations.

Infrastructure construction will be the leading sector for growth, but the other construction will also see healthy growth given the positive outlook and the rapid expansion of the country's middle class.

Indonesia's Master Plan summary

- To accelerate the development of various existing programs, boosting value added oriented, increasing infrastructure development and energy supply, developing human resources as well as science and technology
- To expand Indonesia's economic development across the country equally

The plan highlights increased national connectivity as a matter of urgency: "In 2010, 53 percent of Indonesia's population lived in urban areas. It is predicted that by 2025, the population in urban areas will reach 65 per cent." However, the plan is wide-reaching in its scope and does not focus entirely on this. Its makeup covers tax holidays for selected industries down to climate change issues expected to impact the country keenly.

400
The level of investment in USD billions that is envisaged by the master plan

1.7
The targetted budget deficit for Indonesia in 2013 expressed as a per centage of the national GDP

40
The maximum percentage by which Indonesian minimum wage will rise this year

timetric

Market analysis and data by Timetric, part of Tunnels publisher WMI

Indonesia has attracted massive foreign direct investment (FDI) in recent years, with the total rising to USD 24.6bn in 2012. However, the share attracted by the construction sector dropped to USD 240M in 2012 from USD 618.4M in 2010.

FDI in construction dipped only slightly in 2008, before continuing on an upward trend in the following two years, but the slump in 2011-12 is a concern for the government as it tries to boost investment in infrastructure construction.

Although FDI in the construction sector has disappointed, domestic firms ramped up investment spending in 2012. According to data from the Indonesia Investment Coordinating Board, total domestic direct investment in construction soared to around IDR 4.6tn (USD 470M) in 2012. However, this followed two years of weak domestic investment in construction, averaging just IDR 666bn (USD 70M) a year.

The government is trying to kick-start rapid development of the country's infrastructure, the state of which is currently a major drawback for investors. The government has already announced its intention to boost infrastructure construction spending, with proposals to spend IDR 194tn (USD 20bn) in 2013, up from IDR 169tn (USD 18bn) in 2012.

WAGES

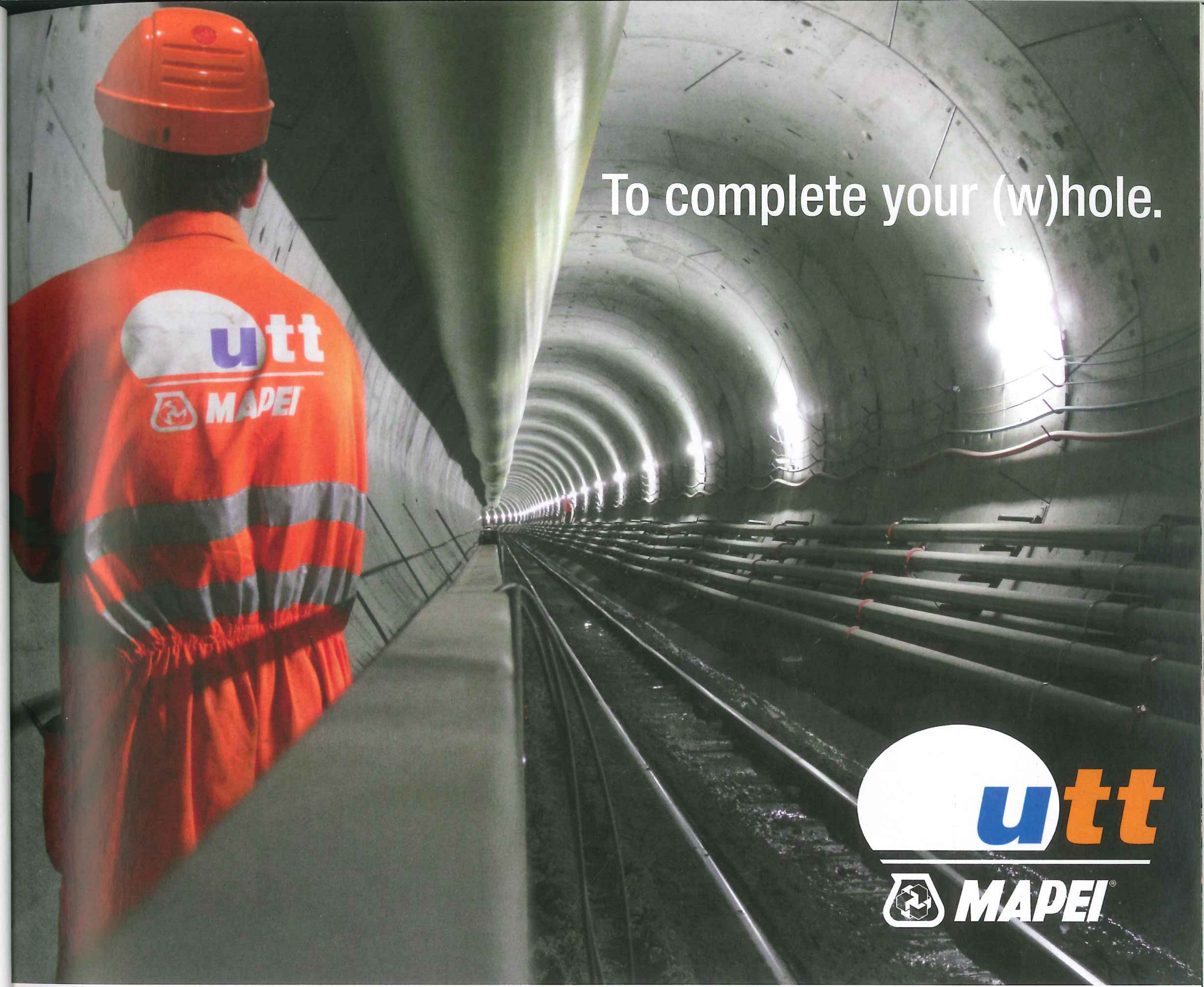
Around seven million workers, some six per cent of the total labour force, were directly involved in the construction industry in 2012. This was double the number employed a decade or so ago. However, the rapid growth of the construction sector and the high demand for construction workers has seen labour costs rise on a steep trajectory. The wages and salary index calculated by Statistics Indonesia show that salaries and wages have increased by 19.3 per cent year-on-year on average in every month since 2009, much above its long term average of 3.9 per cent, reflecting strong activities in the sector.

Wages in general will remain on an upward trend in the coming years. Indeed, there will be a particularly sharp rise in 2013 in line with the government's plan to allow minimum wages to increase by up to 40 per cent. Given the large portion of informal workers in construction, changes in actual wages are lower than increases in minimum wages.

OPERATING TRACK RECORD A RISK

Despite favorable conditions, the construction sector in Indonesia is set to face some challenges. The government appears determined to push ahead with its plans to invest in improving the country's infrastructure. However, given long-standing problems in executing budget spending plans, there is a risk that the government will fail to proceed with these infrastructure projects in a timely manner.

There are also persistent worries over Indonesia's excessive bureaucracy, while corruption is also another factor diminishing the quality of Indonesia's business operating environment



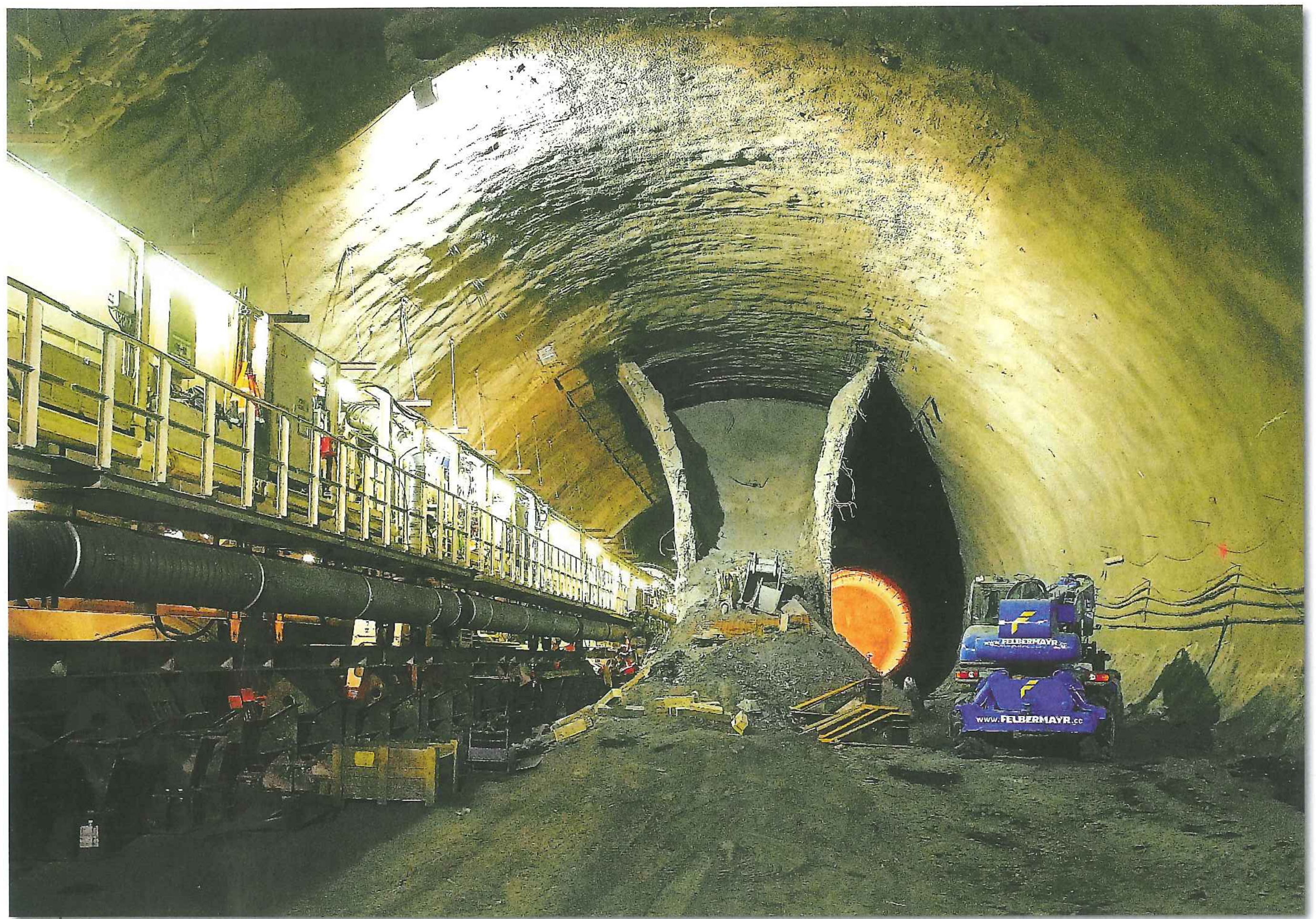
PRAGUE METRO

Ermin Stehlik and **Vaclav Soukup** of Metrostav return with the most recent chapter, and final part of the article, on Prague Metro's history. In this portion, EPBMs fire into action on running tunnels on the V.A. extension

Above: TBMs have constructed running tunnels in recent years

THE LONG-awaited turning point in construction of running tunnels came about in 2010, when Metrostav purchased two Herrenknecht TBMs for the metro V.A extension. The machines are EPB type, production numbers S-609 (Tonda) and S-610 (Adéla). The names were given to the machines by children from Motol Hospital. From 2011 the TBMs bored more than 4km of running tunnels from the Vypich construction site to the existing metro station Dejvická. The shields are 6m in diameter and the segmental lining is 5.3m/5.8m in diameter, with the ring configuration 1.5m wide in a 5+1 configuration. Rings are universal, with horizontal and vertical tunnel alignment controlled by turning the tapered ring.

The two-component grouting behind the lining is performed continuously with boring. The transport of segments and other materials is by multipurpose service vehicle (MSV), each with an 18t



Above: Reusable steel structure with Tonda at Cerveny vrch

capacity, and belt conveyors were used for muck removal. TBM assembly and launch took place at the Vypich site, and logistics were later switched to the E2 site (the construction site in the vicinity of Cervený vrch housing estate and Evropská Street) only after TBM Tonda reached Cervený vrch station, or ended just before this station (in the case of Adéla). Afterwards all operations were transferred to the E2 site with an open construction pit in close proximity to the Evropská trída.

During their journey, the EPBMs were pulled through the following stations: Petriny, Veleslavín (including a short, open pit in front of the station) and Cervený vrch, as well as through the construction pit on the E2 site. Before reaching the existing station Dejvická, where they were dismantled, they had to pass through a short tunnel mined perpendicularly to the alignment, which will first serve for removal of dismantled TBM parts and later technology equipment will be put there. The launch of machines at the Vypich site, and in the E2 open pit, was accomplished with the help of heavy launch frames supplied by Herrenknecht. For the restart operation in all stations another way had to be found due to the limited space in tunnels.

At the ends of stations, starter tunnels were mined and in them steel collars anchored to the primary shotcrete lining. After moving the shield inside, steel braces were welded to the collar and these gave support to the shield thrust cylinders during the restart operation.

During the negotiation with Herrenknecht, and for factory and site acceptances, Metrostav employed John Foster, the prominent TBM expert from the UK. EPBM boring was successful, and the required skills for assembly and operation were mastered rather quickly. During the assembly, and later during operation, a number of specialists from Herrenknecht and its sub-companies H+E and VMT were present on the site. Many other companies supplied material and technical help, including BASF, Mapei and Condat.

Segment production was by Doprastav Bratislava at their segment factory in Senec, with nine sets of stationary moulds supplied by Herrenknecht Formwork. The production was done without heating, and a daily production rate of nine rings. The segments were fitted with neoprene gaskets from Phoenix company. In the right running tunnel from the E2 site to the Cervený vrch station, 10 rings with steel fibre reinforcement were installed, also produced in Senec.

There was no experience with modern TBM technologies, and the last experience with TBM mining was in the 1970s. Moreover, even in terms of modern TBM technologies some of the latest advancements were applied, which are not always seen elsewhere. These were namely belt conveyors, two-component grouting and railless transport. Belt conveyor transport is being seen more and more for continuous excavation, and besides the financial advantages, worldwide usage was also an argument for preferring it to rail transport.

The belts began operation at the Vypich site, where all the drives, transfers station and storage towers were, before transferring them to the E2 site. Together with the conveyor belt supplier, H+E Logistic, a series of challenges were solved, for example the transfer of muck from two conveyor belts to one in the twin truck NATM tunnel, the length of belt when using just one drive from Vypich beyond the E2 site, or the steep inclination of belts on the same site.

Two-component grouting, as the term suggests, is mixed from two components, A and B. Component A is a mix of cement (300kg), bentonite (35kg), water (800 litres) and plasticiser (8kg). The volumes in brackets are valid for one cubic metre of the mix. Component A is mixed on the surface and is transported to the tank on the TBM by pipes. To allow pumping the mix has to stay stable for 72 hours. From the tank on the TBM the mix is pumped via pipes integrated directly in the tail skin into the space behind the assembled ring. Component B, 'water glass' is added with a volume of seven per cent and mixed with component A in the mixing box, which is 1.2m from the end of tailskin. After adding component B an approximately 20 seconds wait sees the mix take on a gel consistency, which prevents its washing out in the case of underground water inflow. At the start of boring there were often breaks and interruptions and it was obvious that the system, against all declared advantages over the more conservative method with cement mortar, will require regular maintenance. This is valid mainly for the last section of pipes from the mixing box to the end of tailskin. Significant improvements were patented improvement (P. Hybský and J. Kafka, both from Metrostav), where in the mixing box the silicon hose was attached to the component B outlet and therefore the mixing and gelling happened at the end of the tail skin.

Both machines were equipped with 'CBP-Tunnel construction information system', which was supplied together with other systems by VMT. The system continuously collects and evaluates all

2014
The Prague Metro will celebrate 40 years from the opening of its first line next year

Ermin Stehlik
Ermin is the tunnelling specialist for Czech contractor Metrostav. He has in past years worked extensively with *Tunnels* and has decades of experience in the industry

Vaclav Soukup
Vaclav is the immediate past director of Metrostav's Division Five, the arm of the contractor that specialises in tunnelling and underground construction works

the available data and transfers them in the form of messages and reports on the displays, either directly on the TBM or in the offices of authorised staff.

Both TBMs completed their boring on 26 November 2012 with a double breakthrough.

STATIONS, AND PULLING TBMS THROUGH THEM

On Line V.A there are three mined stations. Petriny (constructed by Metrostav) and Cervený vrch (by Hochtief) are single vault stations, while station Veleslavín (by Subterra) is a three vault station, built by NATM with reinforced concrete lining.

Single vault stations are similar

Above: Adela in Petriny station

Below: Segment test arrangement at the Senec factory

to Kobylisy Station on metro line IV.C, the difference is the added complication by both TBMs being pulled through partially excavated stations. In the case of Petriny Station, after completing side drifts, the construction of the station was partially interrupted and temporary structures to pulling the TBMs were built. In this case these were reinforced concrete cradles with cast in rails serving to move the shield, the backup moved on the temporary invert from concrete segments laid on the sand layer. Temporary concrete structures were later demolished as the station construction progressed. The notable feature of Petriny Station was the fact that due to the existence of an access tunnel located between the running tunnels, the middle part of the station could be excavated even during the period when both side drifts served for TBM logistics work (i.e., ventilation, piping, transport).

The total excavated profile of the station is 265m², and the width of the excavation was 22m with a height of 15.5m. Two-thirds of the excavated profile was in a waterbearing sandstone layer, the lower third was in claystone. To prevent the negative impact of the station body on the underground water flow, the system of drainage outside the primary lining was put into operation, allowing water flow under the station. The final lining is cast in-situ reinforced concrete with intermediate waterproofing, sprayed waterproofing has been applied on both station face walls.

Through the construction pit in front of the mined Veleslavín station and through both side tunnels with primary lining, based on experience with previous pulling of the shields, these were pulled through using prefabricated steel structures, which enabled repetitive usage for pulling through the open pit at E2 and through the station Cervený vrch. The steel structures (nicknamed 'Lego'), which were easy to assemble and after TBM passage and fast to dismantle for reuse, were designed by the site engineers.

Veleslavín Station was designed with three-vaults to minimise the height of the excavation, compared with a single vault station, to avoid the excavation entering the upper deluvial sediments where there was low rock overburden.

As far as the future of metro construction is concerned, all involved hope the **envisioned Line D** will occupy the near, rather than far future

However, during tunnel excavation in the upper parts of the face, the heavily weathered shale and deluvial sediments were encountered anyway.

After the excavation of side tunnels and the installation of the primary lining, the TBMs were pulled through the station, but further activities had to wait for logistical support to be transferred to the E2 site. This included application of sprayed waterproofing and final lining casting, including the columns. Only afterwards the excavation of middle tunnel could start.

A new feature here is the application of sprayed waterproofing in Veleslavín to the entire station.

The excavated profile of the (single vault) Cervený vrch station is 20m wide and 15.5m high with a total excavated area of 225m². The station was excavated in weathered shale and blocky quartzite, the construction complicated by the presence of residential buildings and therefore it was also necessary to minimise settlement. To stabilise the excavated profiles, a number of additional measures such as grouting and protective umbrellas had to be applied, this consequently caused delays, and before TBM arrival the excavation was not finished as planned.

Therefore after completing the process of pulling the TBM through the station, the excavation of the middle part re-started and contrary to Petriny Station the temporary drift side walls were removed at the same time. The safety of the site was ensured by installation of temporary steel walls, which prevented falling of pieces of primary lining into the space of side drifts, where the logistic of TBMs was continuing without interruption.

Beyond Cervený vrch there was still one place where it was necessary to get both machines through, the smaller, mined tunnel perpendicular to the alignment, with an overburden of only 7m, which was in excavated in advance from the E1 site, located in close proximity of Evropská Street. The tunnel of 120m² cross-section and 37m long was excavated by NATM with number of additional measures applied, mainly jet grouting. Before the TBM arrival the support collars consisting of shotcrete with lattice girders and mesh was installed around the future opening for TBMs. To avoid similar problems with restarting the machines, as was the case with stations and open pits, a special method, similar to a method used on a Herrenknecht TBM in Sweden was applied.

The concrete cradle to approximately half of the TBM diameter, with its inner face stepped to ensure minimal cutting of the cradle concrete, but at the same time providing sufficient support both in horizontal and vertical directions.

No other support structures were necessary, because the machines continuously built the segmental lining, which provided support for pushing ahead. The stability of lining, of which half upper part was 'in the air', was secured by cables encircling and stiffening the lining, the lower part in the cradle grouted with a two-component grout.

REVIEW FROM 1989 UNTIL PRESENT

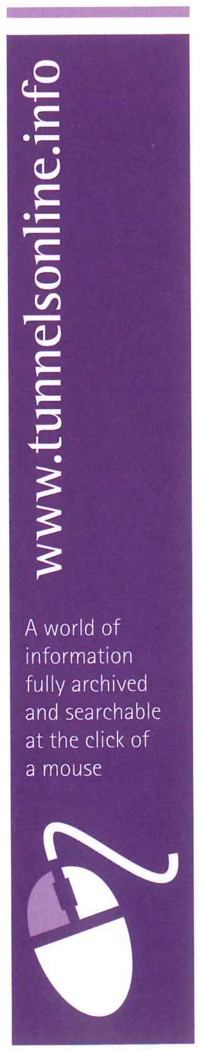
Without any doubt it can be said that Czech (and Slovak) tunnelling has reached the world standard, and not only on Prague Metro construction. The final missing link was the application of modern TBM technology, which although somewhat delayed, finally arrived. For NATM applications, state-of-the-art equipment is used. And for tunnelling crews the most striking difference is the absence of hand work - mainly drilling. The latest waterproofing systems are in use, and with increasing frequency even sprayed waterproofing is employed.

There was a development – in the authors' opinion an unwise one – in the design of primary shotcrete lining (with lattice girders and meshes). The main element of NATM is the utilisation of the bearing capacity of the surrounding ground with the help of bolting, and the shotcrete with lattice girders and meshes is used to keep the integrity of the load bearing ground arch.

But the original idea of using relatively soft primary linings and letting the ground, activated by help of bolting, take the load, was somewhat lost along the way and we are getting primary lining thicknesses up to 500mm, which is basically against the declared NATM principles. But in some cases the reason given is that tunnels are mined with very low overburden in built-up areas, making this a case of using reinforced shotcrete and not NATM. On the other hand, a step in the right direction is the application of unreinforced secondary linings, but this has not been the case in metro tunnels.

A trend to attempt to calculate and model everything can be observed since the start of the 1990s, and is related to the development of hardware and software suitable for finite element modelling. Today it is possible, in a relatively very short time, to give the clients coloured reports with calculation results, and it is forgotten that the

The main element of NATM is utilisation of the bearing capacity of the surrounding ground



results and their interpretation are heavily dependant on applied parameters, which are often only estimated, and usually involve safety factors, or rather protection of the worker himself.

The beauty of tunnelling is that there is always something unknown ahead, there are always some surprises, and therefore tunnelling is sometimes called an art. We should protect this attribute of our business, even into the future.

There is still a difference in comparison to other advanced countries in respect to tunnelling practises, and it is also the case with the V.A extension: The absence of permanent supervision by the client. The rule should be that the supervisor must work the same hours as the contractor, 24 hours a day, seven days a week.

FUTURE OF METRO CONSTRUCTION

As far as future metro construction is concerned, all involved hope the envisioned Line D work will occupy the near, rather than distant future. In the most recent period some basic changes have taken place, both in the line layout, and operational technology. But in any case, the running tunnels will be built by TBM technology, with the mined stations excavated by NATM.

Therefore it would be helpful to summarise the latest experience from the contractor point of view, gained during the construction of Line V.A and apply them to design of Line D. Both machines on the V.A line had, during their 4km journey, to pass through three stations under construction and through two open pits (one of them is the construction pit in front of the Veleslavín Station) and finally through the tunnel on the E1 site.

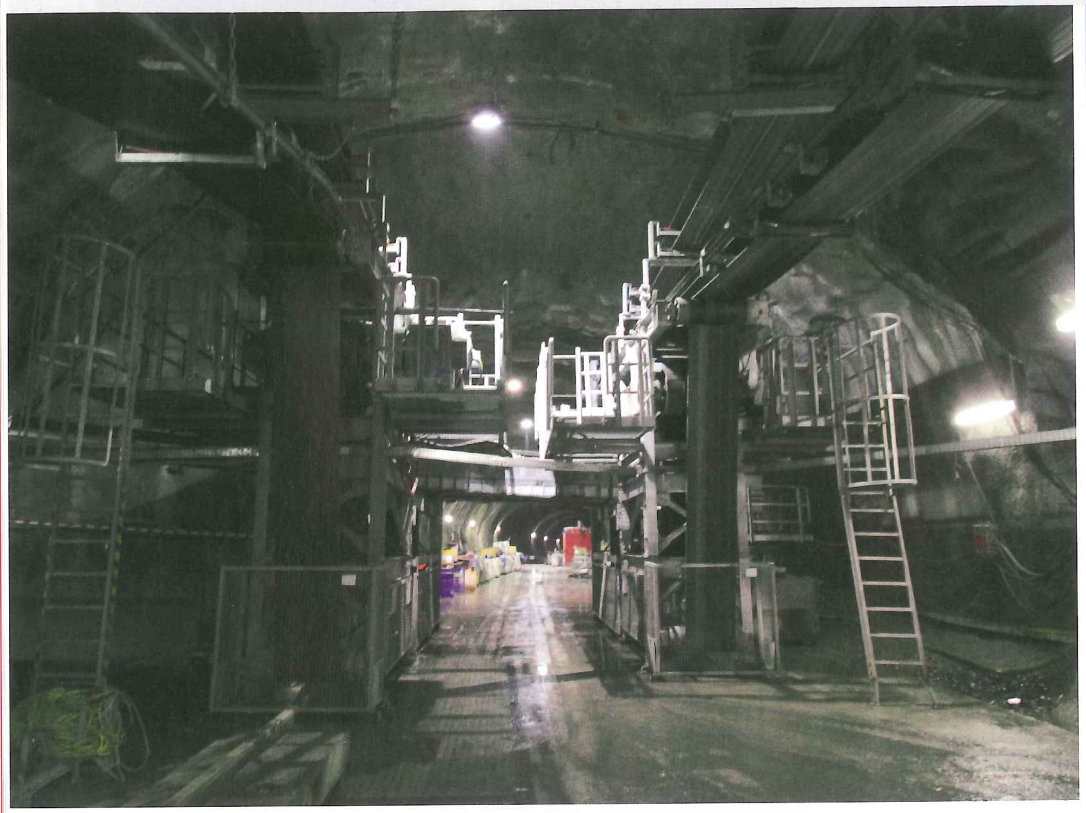
Except for the E1 site there was always the need to restart the machines. And although the site engineers came up with innovative approaches, pulling through and the subsequent restarts required substantial effort as they are technically difficult, costly and they represent time delays not only to the TBMs themselves, but they delay station construction and consequently the whole line. Besides, pulling the TBMs, the eventual dismantling and any other movement should be minimised, if not avoided entirely. Otherwise delays and growing costs would be even more prominent.

The existing metro system show itself as functional and very reliable, therefore the new metro Line D should be compatible with other metro lines and shall use their facilities. For sure the running tunnels diameter shall stay the same, allowing interchange of trains between the metro lines. The design should, to maximum extent, respect the realistically required capacities, and also the full and economic utilisation of TBMs shall be a priority.

CONCLUSION

The construction of the Prague Metro already has a long and rich history. In 2014 it will be the 40th anniversary of the opening of the first line. Despite the brief interruptions in construction, caused by either the political or economic situation, metro work has been in progress for 47 years.

The tunnelling community should put its best efforts into helping the trend continue, through the design and construction of economical solutions, which allow the continuation of metro construction even through turbulent financial climates

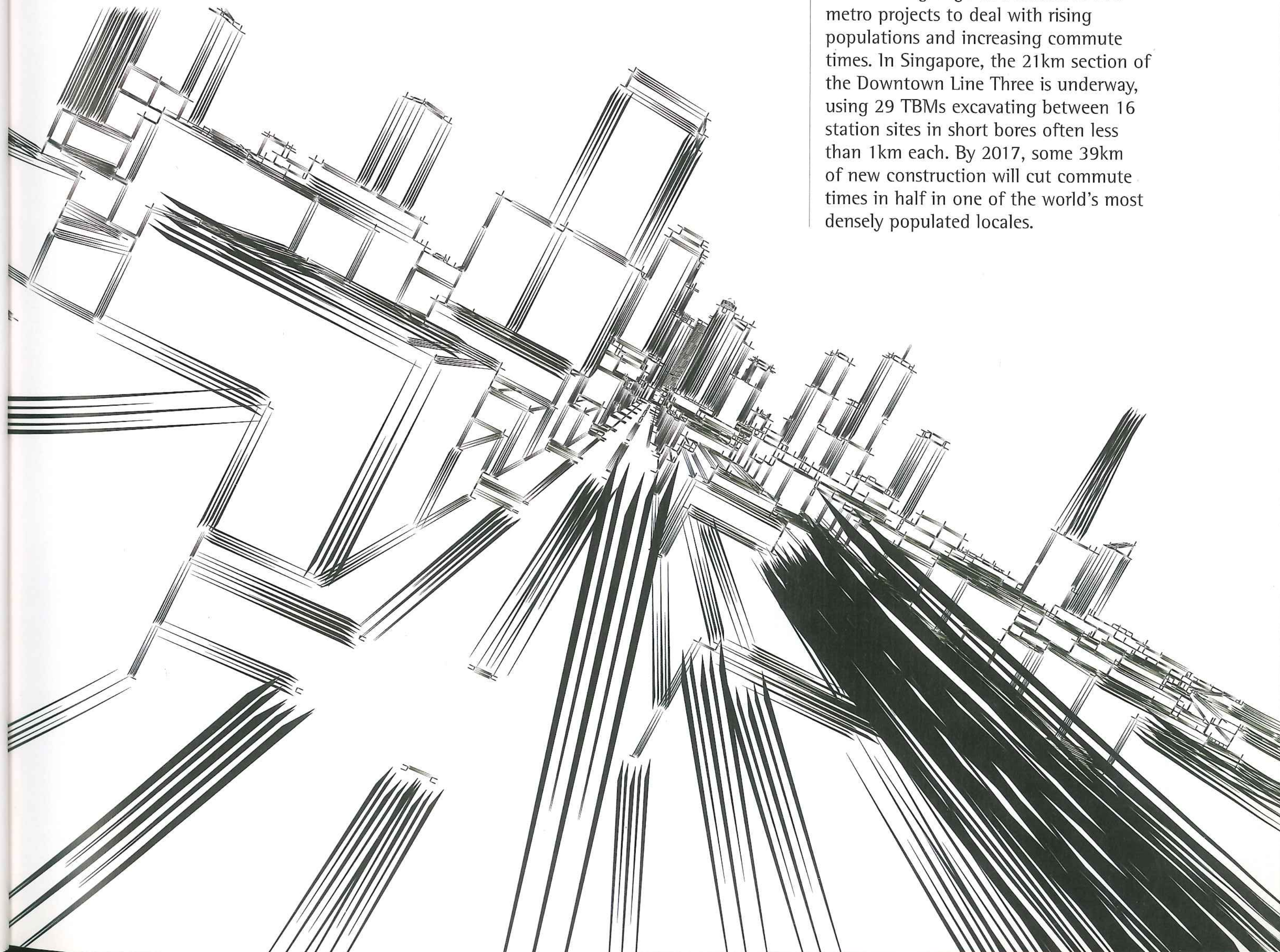


MASSIVE METROS

Desiree Willis, technical writer for TBM manufacturer *Robbins* looks to the logistical changes associated with the rise in grand metro schemes

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

AMID THE hustle and bustle of the world's biggest cities, one thing becomes clear: traffic may be the greatest obstacle in the way of increased productivity. From Moscow to New Delhi to Singapore, governments are initiating large and extensive new metro projects to deal with rising populations and increasing commute times. In Singapore, the 21km section of the Downtown Line Three is underway, using 29 TBMs excavating between 16 station sites in short bores often less than 1km each. By 2017, some 39km of new construction will cut commute times in half in one of the world's most densely populated locales.



The effect of these large projects is equally massive: whole new subway systems built in a single push have a large impact on the local population, are logistically complex, require substantial funding, and can present many challenges to the tunnelling community. Steve Skelhorn, project sponsor at McNally Construction gives his take on the ongoing trend: "Simply put resources are the limiting factor, people being the hardest one of all. We are currently seeing a knowledge gap between the young graduates now getting into tunnelling and those that are a product of the tunnelling boom in the 1980s and 1990s." Given the world's worsening traffic, however, getting the right mix of the proper equipment and people is a challenge that many cities are willing to take on.

THE IMPACT OF BIG PROJECTS

Filling the worker gap continues to be the biggest challenge for contractors seeking to qualify their bids: "There has been a lull in work over the last 15 years with many contractors doing one or two contracts simultaneously. Consequently, contractors did not supplement their crew with additional people. With the increase in workload over recent years this has put considerable strain on contractors. Finding skilled people even to pre-qualify is now a challenge," said Skelhorn. The changing face of tunnel projects, such as the use of dozens of machines simultaneously for short tunnels, is also altering the TBM manufacturing and supply chain: "The other logistic problem we have is equipment. For a local tunnel contractor with 90 per cent of work in their back yard, equipment ownership used to make sense and was a major advantage – mobilisation from one project to another was simple.

"With larger and larger projects, and geographically distant ones, the equipment ownership side has diminished. TBMs are now procured for a project as opposed to using an existing machine and making the project match."

Skelhorn cited other variables as well, such as the local effects of big international contractors on smaller contractors and the available resources. Of the biggest challenge, though, he remained certain: "Anybody can buy additional equipment, but not everyone can find the additional right people."

However, international communities of tunnellers are coalescing on large projects in Moscow, India, and Singapore, where they are gaining experience on a grand scale.

140
The length of line to be created in kilometres for the Delhi Metro Phase Three expansion

50
The number of kilometres of new rail built by Moscow in 2012

MASSIVE METRO: MOSCOW'S MASTER PLAN

In Russia's capital city of more than 12 million people, the average Muscovite has become accustomed to daily commutes of two hours or more. To ease the perpetually slow flow of traffic, the Moscow Government has initiated a major scheme that consists of at least 50km of new metro line by 2016, and more than doubles that by 2020. At its current pace, Russia's rate of metro construction will be second only to China.

The metro system, nearly entirely underground, involves the use of dozens of mixed ground EPBMs: the largest simultaneous construction by TBM that has ever taken place in the city. The compact jobsites, complex ground conditions, and tight construction schedules are all challenges that are being met head on, using customised machines, conveyor muck haulage systems, and an army of skilled personnel.

Moscow's Metro Development Program, unveiled in 2012, calls for 150km of new metro lines within the next eight years. Work thus far has been around the clock, with close to 18,000 workers and specialists engaged in the projects. Their number is expected to reach 35,000 by the end of 2013.

In 2012 alone, 50km worth of new rail were built at 69 different sites. Currently, the effort is largely aimed at preparing the sites where the future stations and lines will be built. This task is a challenge due to the density of Moscow, it is not easy to find appropriate sites that can host train depots, stations, ventilation chambers, emergency exits, and other facilities for the metro. In those areas that have already been designated for metro construction, many utility and communication lines must be relocated.

In a press release issued by the Moscow Government, Marat Khusnullin, deputy mayor for urban development and construction, spoke about the project's unprecedented scope: "Unfortunately, there is a complication related to the lack of existing construction projects, and therefore the first thing we had to do was to invest in planning and design activities," said Khusnullin. According to the deputy mayor, there has been a shortage in the city of planners and skilled construction workers. Thus, the priorities under the new program are to ease the load at the busiest stations and lines, to revise construction schedules, to build interchange centers and parking lots near metro stations, and to promote underground transit in the city's outer districts. Plans also call for a third, 42km long interchange circuit that will have a considerable impact on the congestion of some of the metro's busiest lines.

The entire program will bring the Moscow Metro system to 451km in length and 252 stations at a cost of approximately RUB 100bn (USD 3.2bn) per year. "This country has never built a metro system on this scale, even in the best Soviet years," said Khusnullin.

MIXED GROUND TUNNELLING

Tunnelling is currently underway at dozens of compact jobsites. Most of these jobsites are characterised by Moscow's challenging mixed ground conditions including fine sand, gravel, loam, stiff clays and boulders. As such, each EPBM must be designed with customised characteristics for the geology. Three new Robbins High Performance EPBMs and one refurbished machine are up to the challenge: The EPBMs, operating at various sites in western and southern areas of the city, are the first in Moscow to use electric variable frequency drives (VFDs). The high thrust and torque capabilities of the machines allow for faster excavation while minimising disturbance that can lead to surface settlement. Active articulation on the machines will enable them to excavate tighter curves without the risk of segment deformation that is present when using passive articulation. Mixed ground cutterheads reinforced with abrasion-resistant wear plate give the option of changing out carbide knife-edge bits with 17-inch disc cutters depending on the conditions.

Two 6.6m diameter Robbins EPBMs are excavating left and right-hand tunnels, each 1.8km in length, for contractor Engeocom. A third, refurbished machine for Engeocom, nicknamed 'Julia', is also excavating a 2km section of tunnel. The final machine, a 6.2m diameter Robbins EPBM with mixed ground cutterhead, is boring a 1.9km section of tunnel for contractor USK MOST. All four machines are utilising Robbins continuous conveyors in the mixed ground conditions.

RUSSIA'S RECORD BREAKER

The Robbins machine at USK MOST's jobsite was launched in winter 2012 from a 15m deep shaft. The machine has been excavating in dense clay and fine sand. "With the homogenous soil conditions, we have been using foam and conditioner to keep the earth balanced and for easier muck removal," said Vadim Bocharov of USK MOST.

By spring 2013, the machine had achieved a record for EPBMs in Moscow, excavating 29.4m in one day, 150m in one week, and up to

Above: Five Robbins mixed ground EPBMs are excavating portions of Singapore's Downtown Line, a massive project using 29 TBMs simultaneously

Above (left) and below: EPBM at the Moscow Metro achieved a Russian advance rate record for excavation of 29.4 m in one day

500m per month. "The soil condition, crew experience, rigorous schedule, continuous conveyor, and the reliability of the TBM are all factors that helped achieve the record," said Bocharov.

The TBM is scheduled to break through later in spring 2013. After its initial excavation, the machine will be disassembled in the receiving station site and launched on an additional 1.4km tunnel in the first quarter of 2014. Additional work for USK MOST includes 8km of tunnel and seven stations using multiple TBMs including two Caterpillar and two Herrenknecht EPBMs.

The USK MOST work is just one part of dozens of simultaneous construction operations underway in Moscow. According to Doug Harding, Robbins vice president of sales, mixed ground TBM excavation in Moscow is the best way to ensure the projects are completed within schedule and on budget: "High Performance type EPBs with properly specified muck haulage systems are the only cost effective solution here, due to the deep nature of the stations and tunnels required for the metro."

A MONSTER UNDERTAKING

New Delhi, India, a city of over 16 million, is also home to some of the world's busiest traffic. In answer, the Delhi Metro Rail Corporation (DMRC) has built two phases of the Delhi Metro, with a third phase just starting up. Currently the metro is 190km with 142 stations.

In the Delhi Metro Extension Phase Three, an additional 140km will be built throughout Delhi and connecting to neighboring cities Haryana, Faridabad, and Bahadurgarh. Some 50km of the new ring lines will be built underground. "As far as the benefit of Delhi people is concerned, any mass transit system is a benefit to the public. It will decongest many roads, as a large number of people will shift from road to metro. Not only that, but the new line will provide a great support to the working class who commute between Delhi and Faridabad and Bahadurgarh (Haryana), as they can stay in those areas where the standard of living is quite a bit cheaper than Delhi," said Jitender Tyagi, director of projects for the Delhi Metro Rail Corporation.

The underground portion of rail line was proposed for aesthetic reasons and due to the available space in densely populated areas. "Right now four TBMs are currently working but Phase Three has just started. We can expect 26 TBMs will be working simultaneously in and around one year from now," said Tyagi. The ground consists of a mixed face with rock, and DMRC expects that all tunnelling will be done with mixed ground EPBMs.

Above: Once complete in 2016, Phase III of the New Delhi Metro extension is projected to carry three million riders annually

Phase Three has a tight construction schedule, with completion targeted for the end of 2016. The logistical challenges of launching so many TBMs simultaneously in order to meet the schedule, admits Tyagi, will be many. "Wherever the TBM is launched, we require some space, as land is not available everywhere, so we are waiting for the allotment of land apart from whatever area we have already. The second problem is utility diversion; there are many times water or sewerage lines are present, which need diversion. Monitoring of 26 TBMs at the same time will definitely be a challenge and for that we are planning a centralised monitoring system, which has not yet been finalised but we are planning to have a centralised server and from there management information will be generated. This will smooth construction management."

Also, traffic management around multiple jobsites requires detailed planning for road closures and service lane closures. When near residential areas, the jobsites will also be subject to noise restrictions at night. The new ring lines are projected to carry three million riders annually, and the DMRC is not going to stop there: "Planning for Phase Four has begun. The initial tender should be finalised by 2015," adds Tiyagi.

MORE BIG PROJECTS

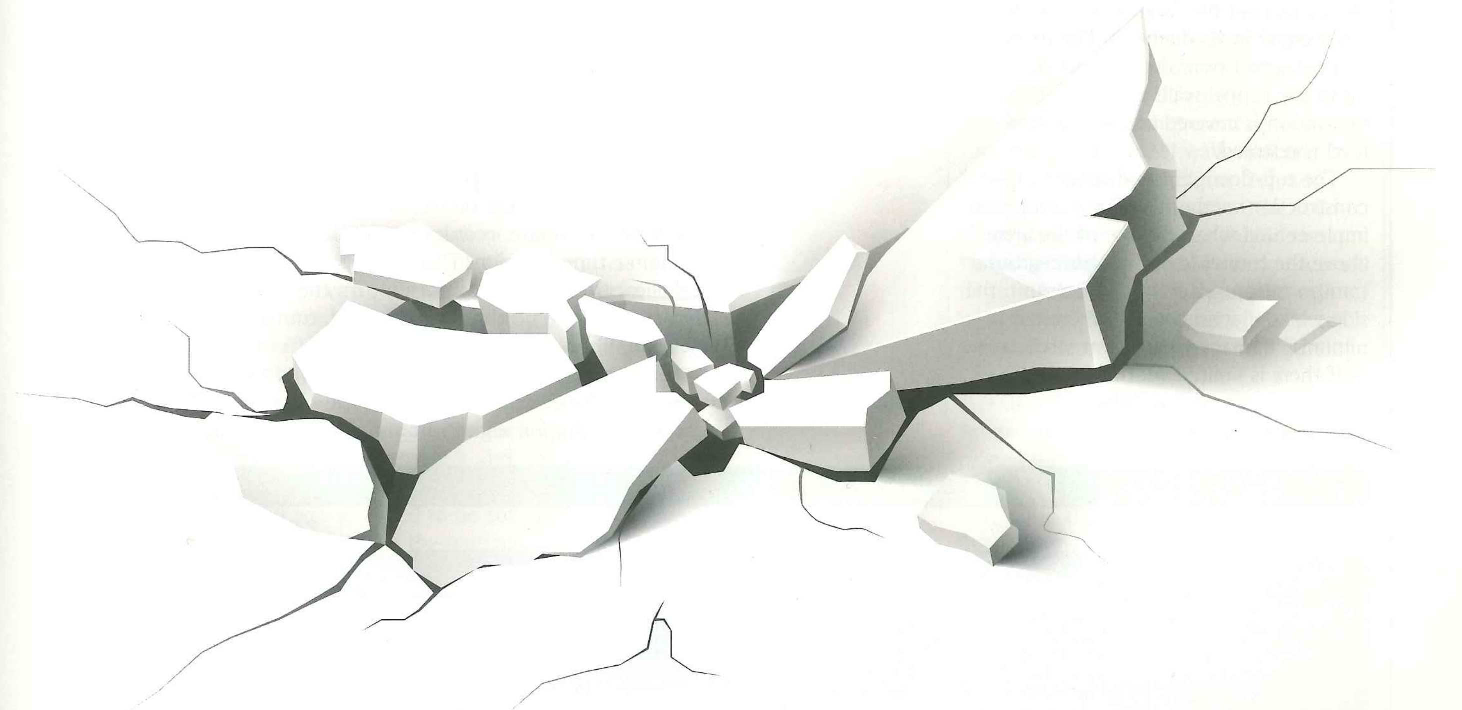
The trend of large metro projects will most certainly continue as the world's populations flock to already crowded urban locations. The DMRC has looked to models in Japan, Singapore, Hong Kong, and Bangkok in researching their design, and hope their system will become a model as well. "Gradually, we have built our own unique metro system. One improvement will be with ring lines, which encourage connectivity. Our previous reaches of metro were built in long radial lines," said Tyagi. Some of the logistical problems associated with the big projects, says Skelhorn, could be helped with a similar approach to the work in New Delhi. "Mega projects by their nature can last many years and tend to be staffed by very large groups. New tunnellers become part of a very large machine and this can last for the duration of the project. Splitting mega projects into smaller parts actually increases the knowledge base down the road." He cited the Channel Tunnel as a mega project that required many tunnellers all at once and sent them all out into the industry at the same time after the project had been completed, creating an imbalance. Of mega projects, it seems that one thing is for sure: they are on the rise, and will be changing the face of the tunnelling industry for years to come

STUDYING STRESS

An extensive parametric study was performed to analyse the effect of tunnel lining stiffness on the stress distribution around shallow tunnels. **Hany El Naggar** and **Taylor Steele** of the Department of Civil Engineering, University of New Brunswick in Canada, share the results

Hany El Naggar
Hany is an assistant professor of geotechnical engineering with engineering, geotechnical and construction experience

Taylor Steele
Taylor Steele is a recent graduate from the civil engineering program at the University of New Brunswick (2013)



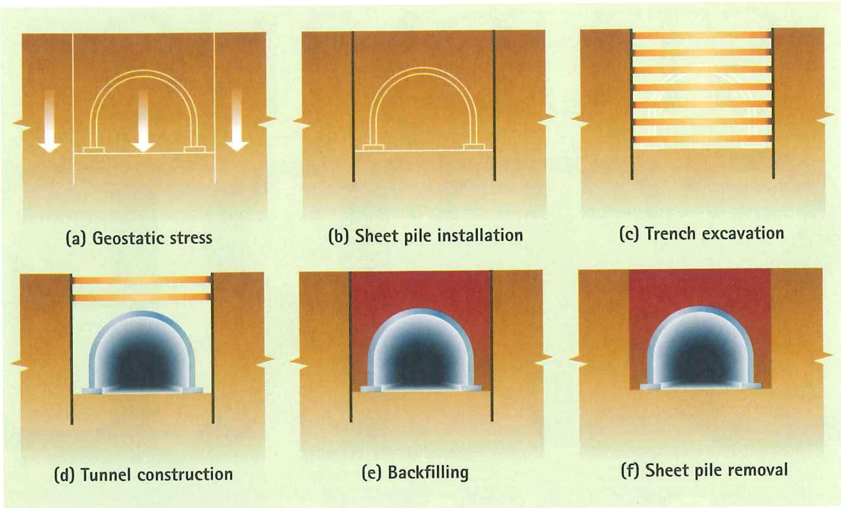
THE CONTINUOUS increase in demand for better and more sustainable travel facilities in major cities has led to a significant increase in the interest in routing roads, railways and metros through tunnels. Due to the abundance of existing underground infrastructure at deeper depths, tunnels in urban areas are often being constructed at shallow depths.

A tunnel is considered to be shallow when the height of cover above the tunnel is not much greater than the tunnel diameter. Generally, shallow tunnels are constructed at depths ranging from 9m to 12m (FHWA, 2009). These tunnels can be constructed by mechanised tunnel boring methods (such as TBMs) or by the cut and cover method. The majority of these shallow tunnels are cut and cover arch-shaped concrete tunnels.

The cut and cover construction technique has been used for many years as a means for building underground transportation facilities. This technique may involve one or both of the two following methods: bottom-up construction and top-down construction.

Bottom-up construction involves the excavation of a trench in which the tunnel is erected. Temporary structures, such as sheet pile walls, secant pile walls, tangent pile walls or sheet pile walls are usually required and installed before the excavation takes place to support it. Providing unreinforced side slopes may require the removal of up to six times more material, and spread an additional three tunnel diameters on either side of the excavation for tunnels with depth of cover equal to its diameter. The tunnel is constructed from the bottom slab, up to the tunnel walls and roof. The excavation is covered and the ground level is restored.

The top-down cut and cover construction method is often implemented when the use of the area above the tunnel (e.g., for above-ground transportation systems) is paramount, the side wall deflections must be limited to minimise damage to adjacent structures or if there is limited width of right-of-way for excavation (FHWA, 2009). Excavation support is installed first,



Above: Figure 2, general construction sequence of the modeled cut and cover tunnel

Opposite (above): Figure 1, geometry of the considered problem (not to scale)

consisting of structures such as slurry walls, secant pile walls or sheet pile walls, which usually become the permanent walls of the tunnel. A shallow excavation is created, where the roof of the tunnel is constructed on grade. The excavation is covered for continued use, while the tunnel interior is excavated from below grade with bracing provided to the support walls. The early cover of the excavation allows for quicker turnover from the beginning of construction to the re-availability of the ground surface. In both bottom-up and top-down construction sequences, de-watering of the work area may be necessary before excavation of the ground material.

For shallow tunnels, the cut and cover method is more economical than any other tunnelling method. However, the cost of cut and cover construction increases sharply with increased depth.

Regardless of the construction method, shallow tunnels in major cities will be situated below surfaces that are densely populated with various structures, from bridge piers and abutments to foundations of high-rise buildings. For tunnels constructed using the boring techniques, the tunnel-soil-structure interaction has been modelled extensively (i.e., Morton and King, 1979; Mair et al., 1996; Schroeder, 2002; Leung et al., 2003; Schroeder et al., 2004).

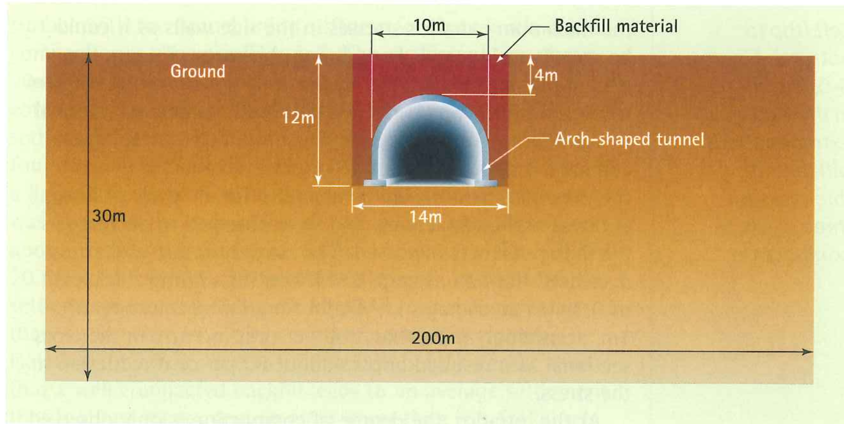
However, the shallow depth of the tunnel in these urban areas will expose it to the zone of influence of many existing and future structure foundations. Shallow tunnels and structure foundations can interact mutually influencing their stability. Hence, it is important to analyse the stress distribution regime around shallow tunnels accounting for tunnel-soil-structure interaction in order to provide an insightful and economic tunnel design. The redistribution of stress around a shallow tunnel depends not only on the characteristic properties of the neighbouring ground, tunnel size, and location, but also on the tunnel lining stiffness.

The scope of this paper will be limited to the effect of the relative stiffness of the backfill and the tunnel lining on the stress redistribution regime around shallow tunnels.

Table 1. Selected backfill soil properties.

Backfill	ϕ (°)	E (MPa)	ν (-)	γ (kN/m3)
Loosely compacted	30	30	0.3	20
Medium compacted	33	50	0.3	20
Well compacted	36	80	0.3	20

Source: ICD Research Industry Survey 2011



An extensive parametric study was performed to analyse this effect on the stresses experienced in the tunnel lining, the vertical deflection of the tunnel crown and the maximum contact pressure transferred from the tunnel's foundations to the ground.

NUMERICAL MODEL

In order to investigate this soil-structure interaction problem, an arch-shaped concrete tunnel 10m wide by 8m height with 4m of cover over the crown was considered. The tunnel walls are supported by two 2m-wide and 0.6m-thick strip footings. The considered soil profile consists of a 30m-thick dense sand layer. The tunnel is constructed in a 14m-wide, 12m-deep excavated trench (see Figure 1).

Finite element mesh

The soil continuum was modelled using the 15-noded cubic strain triangular finite element available in the element library of the PLAXIS finite element package (Brinkgreve, 2008). The lateral boundaries were placed at about 10 times the width of the tunnel in each direction to simulate the infinite medium. The bottom boundary was placed at 30m below the ground surface. The size of the model was chosen such that the artificial boundaries and boundary conditions would have little to no impact on the ground stresses around the tunnel.

Soil model

The material constitutive models for both the ground and the granular backfill were assumed to obey the Mohr-Coulomb failure criterion (i.e., elasto-plastic stress-strain relationship). The criterion assumes linear elastic soil behaviour up to the defined Mohr-Coulomb failure surface. If the failure surface is reached, the soil yields, with corresponding stress redistribution to maintain equilibrium, up to the point where the stress conditions in the soil zones do not violate the yield surface and become again acceptable under the failure criterion.

The ground was modelled as purely frictional soil (i.e., c = 0) with Young's modulus, E = 80MPa, Poisson's ratio, ν = 0.30, and angle of friction, ϕ = 38°. Three different sets of material properties were assumed for the granular backfill representing loosely compacted, medium compacted, and well compacted backfill materials. For all considered compaction levels, the unit weight of the backfill was assumed to be constant to isolate only the effect of the stiffness of the material. In all three cases, the backfill was modelled as purely frictional material. Table 1 presents the considered backfill soil properties.

Tunnel lining model

The tunnel lining and its walls and foundations were assumed to obey the linear elasticity model based on Hooke's law of

14
Metres in width is the tunnel's excavated trench

10
The width in metres of the tunnel in consideration

2
Metre wide strip footings support the tunnel wall

isotropic elasticity. According to the conducted parametric study the tunnel was modelled for wall thicknesses varying from 0.3m to 1.0m. The tunnel lining was modelled as concrete with elastic modulus, E = 30GPa and Poisson's ratio, ν = 0.20.

Simulated construction process

The staged construction technique was used to simulate the cut and cover construction process in different phases. These phases are illustrated in Figure 2.

Initial phase prior to tunnelling

The initial in-situ stresses were set using the Ko procedure. The initial geostatic stresses were established assuming a linearly increasing vertical stress with depth (i.e., $\sigma_v = \gamma H$) and horizontal stresses based on the vertical stress state (i.e., $\sigma_h = K_o \sigma_v$) where $K_o = 1 - \sin\phi$.

To simplify the analysis, the ground water table was assumed to be well below the tunnel.

Simulation of trench excavation

The sheet pile retaining wall was first installed to support the trench sides during excavation (Figure 2b). Then, the soil excavation inside the trench was performed in eight 1.5m excavation steps. This was simulated by incrementally deactivating all of the soil elements inside the excavated zone. After each excavation steps, bracing whalers was installed to support the excavation sides and limit the deformation of the sheet pile wall (Figure 2c).

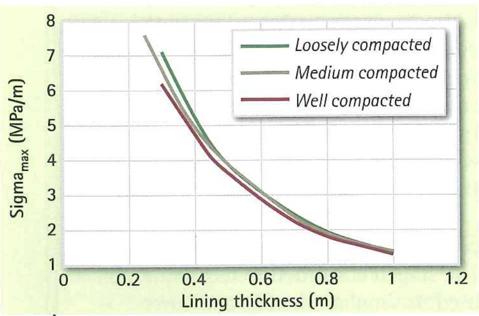
Simulation of tunnel construction

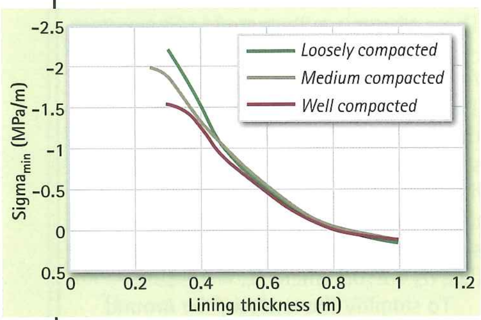
The tunnel construction was simulated by sequentially activating the structural elements representing the tunnel's lining, tunnel walls, and the tunnel's foundations (Figure 2d), and consequently activating all of the soil elements between the trench and the tunnel simulating the backfilling process (Figure 2e). Finally, the sheet pile walls were removed by deactivating the sheet pile wall elements as shown in Figure 2f.

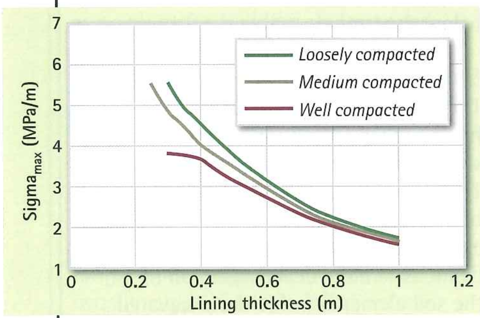
ANALYSIS RESULTS

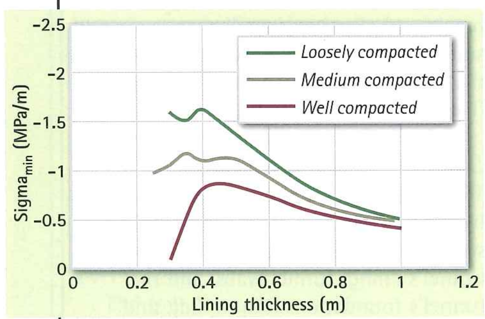
An extensive parametric study was carried out to investigate the effects of the relative stiffness between the tunnel lining and the backfill on a) the stresses in the tunnel lining, b) the maximum deformation of the tunnel lining at the crown, c) the settlement of the ground surface and d) the contact pressure experienced by the tunnel foundations.

In the parametric study the thickness of the tunnel lining was varied from









Left (top to bottom): Figures 3-6, variations in the side wall extrados stress with lining thickness for three levels of compaction

0.3m to 1.0m, also the stiffness of the backfill material was varied to correspond to the degree of compaction (i.e., loosely compacted, medium compacted or well compacted backfill materials).

The following sections present the results of the parametric study.

Tunnel side wall stresses

Figures 3 and 4 show the variation in the maximum stresses in the vertical side walls of the tunnel with tunnel lining thickness for three different levels of compaction at the extrados and the intrados locations, respectively.

The degree of compaction was not observed to have a profound impact on the maximum extrados stresses in the side walls as it could be seen from Figure 3. For a lining thickness of 0.3m, the maximum stress experience by the wall varied from 6.2MPa/m when the trench was backfilled with well compacted material to 7.1MPa/m when the trench was backfilled with a loosely compacted material, about 15 per cent change. In general, the extrados stresses were compressive for all levels of lining stiffness and compactions, and were observed to decrease as the lining stiffness increased. The maximum side wall stress decreased from an average 6.6MPa/m for a lining thickness of 0.3m to an average 1.4MPa/m for a lining thickness of 1m, accordingly more than 300 per cent increase in the cross sectional area resulted only in about 80 per cent reduction in the stress.

At the intrados, the degree of compaction is only observed to have a noticeable impact on the intrados stress in flexible tunnel linings. For stiffer tunnel linings (t > 0.5m), the stress state is almost similar for all three levels of compaction as shown in Figure 4. It can be seen that the intrados stress transitioned from tensile to compressive for tunnel thicknesses exceeding roughly 0.8m. It can be concluded here the axial stress due to the thrust exceeds the bending stress induced by the bending moment. Since the compressive strength of concrete is typically much greater than its tensile strength, this situation is favourable. As for typical f'c = 40MPa concrete, the intrados stress was not observed to exceed 60 per cent of the ultimate tensile strength of the concrete (about 4MPa).

Overall, variances in the degree of compaction had a minimal effect on the vertical side wall stresses compared to the effect of the change in lining stiffness.

Tunnel shoulder stresses

The variation in the extrados stress at the tunnel shoulder's location with the tunnel lining thickness for three different levels of compaction is displayed in Figure 5. For a lining thickness of 0.3m, the maximum stress experienced by the wall varied from 3.8MPa/m when the trench was backfilled with well compacted material to 5.6MPa/m when the trench was backfilled with a loosely compacted material. This trend is expected because as the stiffness of the backfill decreases (loosely compacted backfill), the relative stiffness of the lining increases (with respect to that of the backfill) and thus attracts more stresses. This finding agrees with that of El Naggar et al. (2008). Also, the shoulder extrados stress decreased from an average of 4.7MPa/m for a lining thickness of 0.3m to an average 1.6MPa/m for a lining thickness of 1m. Thus, as the cross sectional area of the lining increase the stress decrease.

Figure 6 shows the variation in the intrados stress experienced in the tunnel's shoulder with tunnel lining thickness for the three considered levels of compaction. Compaction appears to have had a more profound impact on the shoulder wall intrados stresses than it did for the side wall intrados stresses. Also, compared to the vertical side wall intrados stresses, the shoulder wall intrados stresses were tensile in nature for all lining thicknesses. This is due to the fact that higher magnitude of moments presents at the shoulder location that result in higher tensile bending stresses.

Generally, compaction had much more of an impact on the stresses induced in the shoulder wall than it did for the side wall. It can be concluded that as the stiffness of the backfill increases (with respect to that of the lining) more stresses will be attracted by the backfill and the stresses arching away from the tunnel lining.

Maximum ground settlements

The variation in the maximum settlement of the ground surface with the tunnel lining stiffness for three levels of compaction is shown in Figure 7. The settlement was about 20mm for a tunnel lining thickness of 0.3m in loosely compacted backfill, as the thickness increases to 1m the settlement decreases to about 16mm. The same trend was found to hold for all considered levels of compaction. Also, for a lining thickness of 0.3m, the maximum ground settlement was 20mm in the case of loosely compacted backfill and only about 16mm for well compacted backfill case, which is about 20 per cent less than the former settlement. As expected, the settlements for well compacted backfill material were lower than settlements for loosely compacted backfill material. Isolating the effects due to compaction only, it can be seen that a well compacted backfill leads to an average settlement that is about 20 per cent or more lower than it is for loosely compacted backfills.

In general, it can be noticed that the observed settlements decreased with an increase in tunnel lining stiffness. Isolating the effects of tunnel lining stiffness on settlement, it can be observed that the 1m thick lining lead to a ground surface settlement that is about 4mm or 20 per cent less than the settlement when a 0.3m thick lining was used, and is a similar reduction to that obtained by achieving a well compacted backfill. This is likely due to the soil-structure interaction; a stiffer tunnel would lead to reduced tunnel lining deformation and thus reduced volume loss and therefore reduced settlement potential of neighbouringing backfill and soil.

Tunnel crown deflections

Figure 8 shows the variation in the maximum vertical deflection of the tunnel (at the crown location) with tunnel lining stiffness for the three considered levels of compaction. As it can be noticed from Figure 8, the crown deflection is observed to decrease with an increase in both the tunnel lining stiffness and the compaction quality of the backfill. The decrease in deflection is likely due to the fact that the combination of a stiff tunnel lining with a well compacted backfill creates a stiffer medium that is more capable of transferring stresses without inducing as much deformation. A backfill with a poor compaction would be more flexible and would rely more on the lining for support. This can induce more vertical load and thus more deflection of the tunnel crown.

Foundation contact pressure

The variation in maximum tunnel's foundation contact pressure with tunnel lining thickness for three different levels of backfill compaction is shown in Figure 9. The contact pressure is observed to increase with both an increase in tunnel lining thickness and a decrease in compaction quality. As the tunnel lining becomes stiff relative to the backfill material, it carries a higher potential to transfer stresses to the ground. Therefore, the tunnel will play a larger role in stress transfer when compared to the backfill material. Thus, the tunnel wall foundations will carry a higher contact pressure for a stiffer tunnel lining.

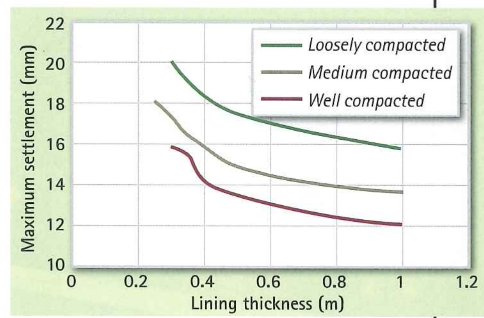
With a better backfill compaction, the backfill material becomes stiff relative to the tunnel lining and thus has more potential to transfer stresses to the ground beneath it through soil arching. This would mean that less stress has to be carried by the tunnel itself, resulting in a lower contact pressure between the tunnel wall foundations and the ground.

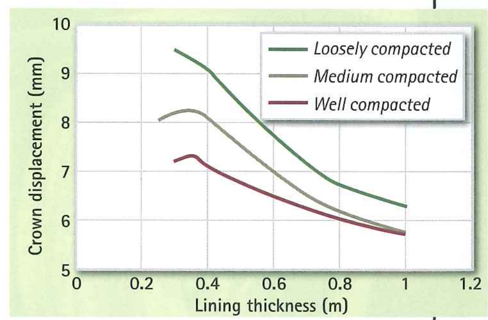
The change in relative stiffness between the tunnel lining and the backfill alters the load transfer mechanism. Interaction between the backfill and the tunnel leads to different levels of soil arching, which will alter the amount of stress transferred to the ground via the tunnel wall foundations.

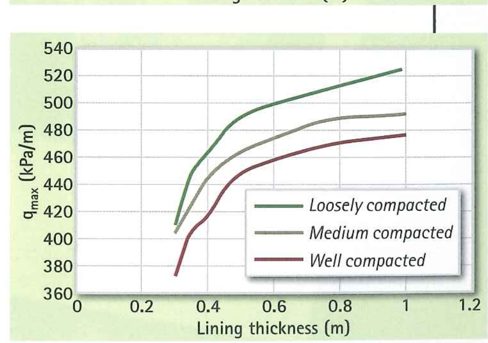
CONCLUSIONS

An extensive parametric study investigated the effects of tunnel lining stiffness and the compaction quality on the stresses in the tunnel lining, ground surface settlement, tunnel crown deflection and the maximum transferred tunnel's foundations contact pressure. The conclusions of the study can be summarised as follows:

1. Both the extrados and intrados stresses in the tunnel's vertical side walls decrease with an increase in the compaction quality
2. Compaction quality has a more profound effect on the stresses distribution in the tunnel lining shoulder walls than on the stresses in the vertical side walls
3. The maximum ground surface settlements decrease with both an increase in tunnel lining stiffness and an increase in backfill compaction quality
4. The reduction in contact pressure between the tunnel foundations and the ground as compaction quality increases can be attributed to arching effects







Right (top to bottom): Figures 7-9, variations in the side wall extrados stress with lining thickness for three levels of compaction

TUNNELS AWARDS 2013

ENTRIES ARE now being accepted for the Tunnels Awards 2013. The biennial awards were relaunched in 2011 to champion the industry's best efforts, greatest achievements and most impressive recoveries.

The awards aim to identify and applaud those that go above and beyond the call of duty to meet the testing demands of clients, budgets, schedule, geology and scope.

The awards will once again be judged by a robust team of industry leaders and supported by the British Tunnelling Society

The Awards

Overcoming adversity

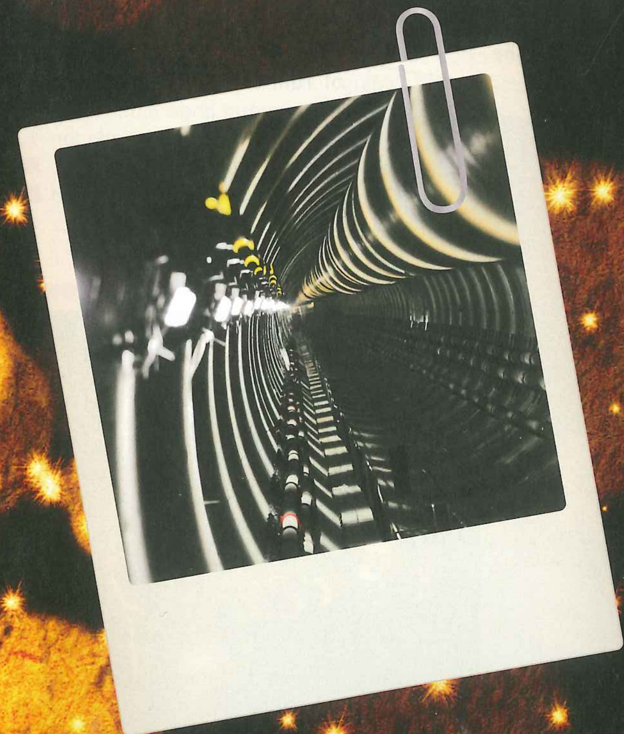
- **Endurance Award**
  For completing a project in the face of numerous or persistent challenges
- **Tour de Force Award**
  For successfully overcoming the greatest single challenge
- **Foresight Award**
  For the early identification and mitigation of a problem in design or construction

Sustainability

- **Investor in Tunnellers Award**
  For services to the education of tunnellers
- **Preservation Award**
  For tunnelling with the lowest impact on the environment through design or construction methods

Innovation

- **Innovative use of Materials**
  For the successful use of materials in unusual deployments
- **Innovative use of Equipment**
  For the successful use of equipment in unconventional deployments
- **Innovative use of Instrumentation**
  For the successful unusual use of instrumentation in site investigation, surveying or monitoring



Submit an entry

Where to enter
Post your entries to Tunnel and Tunnelling Awards, 7 Carmelite Street, London, EC4Y 0BS, UK or email to *awards@tunnelsonline.info*. Do not send more than 10MB of data in any one email. Please make the subject of your email: 'Tunnels Awards 2013'.

Who can enter
The Tunnels Awards are open to all tunnelling professionals, designers, contractors and suppliers practicing anywhere in the world.

How to enter
For display purposes, Tunnels will produce two A3 pages on each submission for the judging panel. For this we will require:

- A 1000-word entry submission written in English answering why you/your nominee/your project is eligible for the award. Accepted file types: doc, txt.
- A maximum of ten images/diagrams is required, and all images must be 300dpi, CMYK colour space and of a large size. Accepted file types: jpg, tiff, eps, ai.
- A high-resolution image of your logo (minimum 300dpi).

We cannot accept any files created in AutoCAD, Microstation, Pagemaker, CorelDraw or Microsoft Publisher.

In submitting the above material, you grant to World Market Intelligence indefinite, worldwide, non-exclusive, fully paid license to reproduce and display all text, images, trademarks, logos and other provided content.

All entrants are encouraged to include copies of preliminary design, alternative schemes explored, information on context, precedents for the design or method and excerpts from working drawings.

Winners
The Tunnels Awards 2013 will be announced in a dedicated supplement to be published with the December 2013 issue of Tunnels and Tunnelling International.

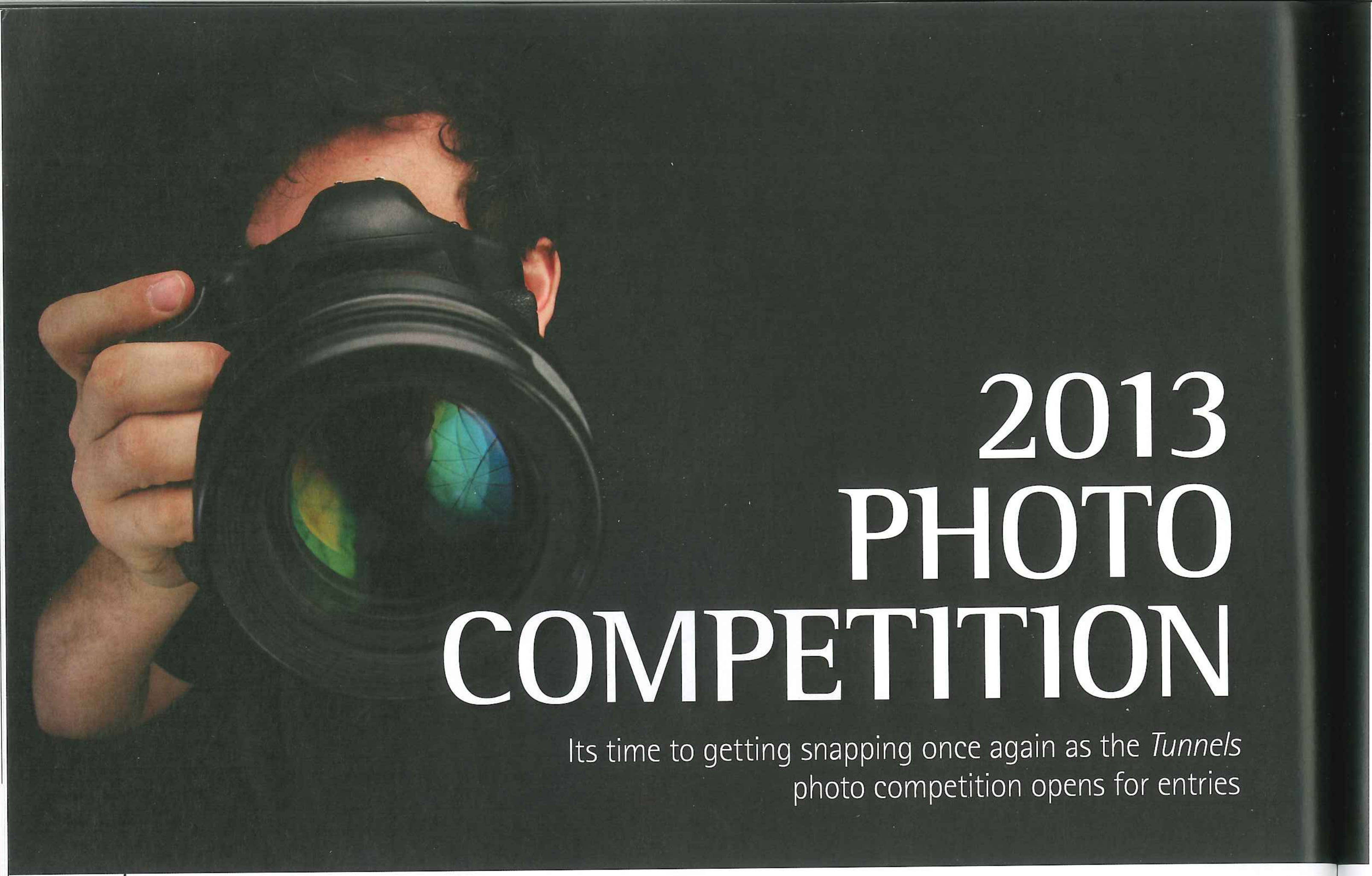
Winning entries will feature throughout the World Market Intelligence product portfolio. If the submission should be shortlisted for any Tunnels Award, the entrant agrees to make available further information and publication-worthy graphic material as required by World Market Intelligence.

Judging
Entries will be judged by a panel of experts, who will select winners. Details of the winners will not be made known until the December 2013 issue of Tunnels and Tunnelling.

Verification of the awards
World Market Intelligence reserves final decision on eligibility and accepts no liability in this regard.

Return of entries
Word Market Intelligence is unable to return any entry submissions.

Entry deadline
The deadline for the receipt of entries and all supporting materials is 1 September 2013. No responsibility can be accepted for non-delivery of materials.



2013 PHOTO COMPETITION

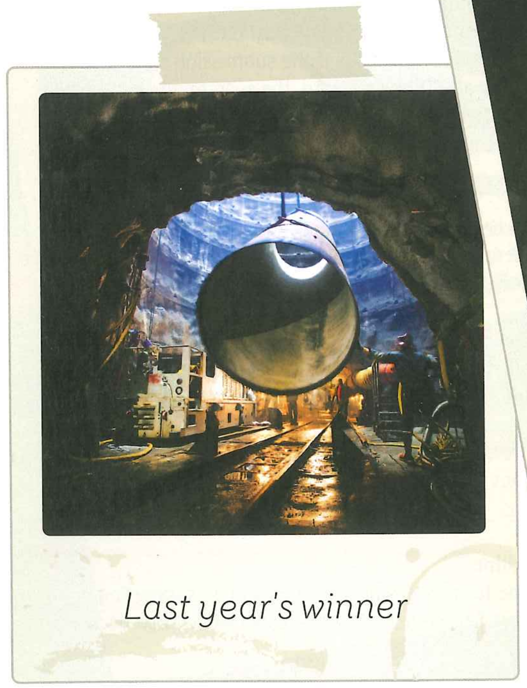
Its time to getting snapping once again as the *Tunnels* photo competition opens for entries

ONCE AGAIN we are giving you the chance to win the latest in digital camera technology and all you have to do is take a classy snap of your tunnel.

Capture the moment that defines a tunnel project. Be it contractors knee deep in mud and concrete or the glossy finish of a newly laid segment. We are looking for the photo that can reveal the true nature of tunnelling.

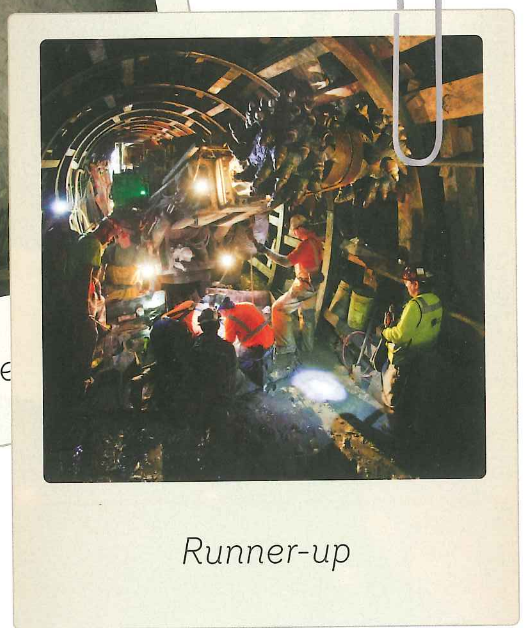
The judges will be scoring on the technical quality of the shot and the moment it captures.

The closing date for entries is 1 September and the short listed entrants will be announced in the September issue of *Tunnels*. The winners will be announced in the Tunnels Awards supplement in the December issue of Tunnels International



Last year's winner

Runne



Runner-up

Top tips

Competition judge Nick Kozak gives his top tips to taking the perfect photo:

- Shoot, shoot, shoot as much as you can.
- Think before you shoot; what are you trying to capture?
- Composition should be a priority.
- Get closer - Robert Capa said; "If your pictures aren't good enough, you aren't close enough."
- Edit, edit, edit, upload and sift through your photographs regularly.
- Be your own critic; learn to identify what works and what doesn't in your photos.
- Look, look, look at others' photographs, both amateur and professional.
- Observe the world through an imaginary lens, even when you're not photographing.
- Show your photographs to others to get feedback.
- Have fun, get a kick out of photography, it will show in your work.

Win

The winner of the *Tunnels* 2013 photo competition will receive GBP 1,000 in camera store vouchers. Two runners up will be awarded GBP 250 each in camera store vouchers.

Entry is free. Closing date is 1 September 2013. The competition is open to entrants from any country. World Market Intelligence reserves the right to withdraw the competition.

The judges

Nick Kozak - Nick is an experienced photographer based in Toronto, who specialises in disaster and construction photography.

...

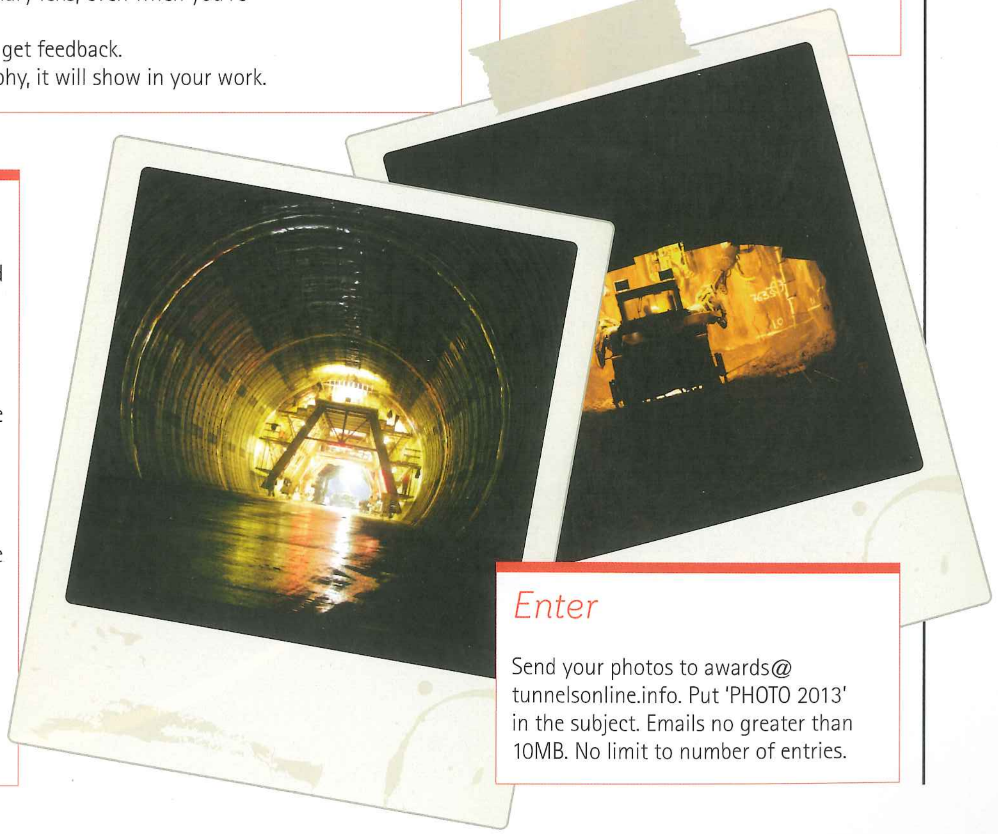
Henrik Williams - Henrik is creative director at *Tunnels* parent company Progressive Media Group. He has more than 20 years' experience in publishing.

...

David Cooper - Responsible for the 2012 *Tunnels* re-design, David has been with Progressive for the past four years.

...

Jon Young - As the editor of *Tunnels* has to sift through hundreds of tunnel photos in an attempt to sort the wheat from the chaff.



Enter

Send your photos to awards@tunnelsonline.info. Put 'PHOTO 2013' in the subject. Emails no greater than 10MB. No limit to number of entries.

SPRAYED OVERBRIDGES

SCL overbridges at Tottenham Court Road. **Andreas Feiersinger** of Dr. Sauer & Partners, and **Phillip Lea** of Halcrow were the authors of this paper, which was presented at the March meeting of the British Tunnelling Society

IN THE first use of its kind, the Tottenham Court Road Station Upgrade (TCRSU) project has designed and constructed two sprayed concrete lined overbridges passing directly over the operational Central Line platform tunnels. As trains and passengers pass underneath the feet of the SCL miners, and they walk over the back of the existing platform tunnels, they have achieved a first on the London Underground (LU) system. Moving away from the traditional three-stage, hand mined solution; the tunnelling operations have created two caverns above the existing platform tunnels into which the permanent linings can be installed. Significant work was completed in order to ensure adequate

ground support was maintained and to minimise ground movements and damage to the platform tunnel linings.

PROJECT OVERVIEW

The major upgrade to the LU Tottenham Court Road Station has been developed to relieve congestion, achieve step-free access and modernise the station. The major civil engineering elements of the LU Station upgrade are:

A. An enlarged sub-surface ticket hall beneath Charing Cross Road, with three new entrances;
B. A combined fire fighting and emergency escape shaft with emergency access tunnels to both Central and Northern Lines;
C. Three new escalators to the Northern Line from the new ticket hall;
D. An additional concourse tunnel adjacent, and parallel to, the Northern Line platforms, leading to three new staircases to access the platforms;
E. An additional concourse tunnel adjacent, and parallel to, the Central Line platforms, with two new overbridges leading to new stair and lift to access the platforms.

Halcrow worked as the multi-disciplinary design consultant for the client, LU to develop the design between 2007 and 2009. The specialist sub-consultant for the sprayed concrete tunnelling works was Dr. Sauer & Partners (DSP). The tender was awarded to the Taylor-Woodrow-BAM-Nuttall (TWBN) joint venture in January 2010 and then Halcrow was subsequently appointed to provide design and site supervision services.

The primary objective of all tunnelling works at TCRSU was to minimise ground movements. To this extent reducing excavated area, speed to tunnel ring closure and controlled tunnel advances were critical.

The primary ground support for the main tunnels is steel fibre reinforced sprayed concrete with a spray applied waterproof membrane located at the boundary between the primary and secondary linings. Secondary linings consist of both traditionally reinforced cast-in-place concrete and steel fibre reinforced sprayed concrete linings.

15
The percent within which actual movements fell, relative to those predicted

Andreas Feiersinger
Andreas works in the London offices of Dr. Sauer & Partners. He has provided design and supervision on the TCRSU for 3 years

Phillip Lea
Phillip has worked for 12 years in the Tunnels and Underground Spaces Department of Halcrow. He has gained his experience working on many UK projects

CENTRAL LINE OVERBRIDGE DESIGN

Overbridges

The new SCL Central Line interchange tunnel extends from the existing TCR station interchange level and runs approximately 110m parallel to the existing platform tunnels. The new overbridges extend from this tunnel, over the westbound Central Line platform tunnel and terminate in an enlarged upper lobby.

From here, traditional hand mining methods are to be adopted to descend between, and break into, the existing platform tunnels to form the new stair and lift structures.

The level and alignment of the overbridges was significantly constrained by a number of existing structures. The tunnels need to tie into the existing station interchange level, minimum headroom requirements must be met on the platform and, to add to this complexity, an existing Victorian brick lined mid level sewer is only 5m clear of the platform tunnel (i.e. lying less than 1.5m above the upper lobby).

New stair and lift structures descend between the platform tunnels from each overbridge and provide additional access to the Central Lines from the existing station interchange level.

The original tendered design was for the overbridges to be constructed by traditional hand mining methods involving significant use of timber and steel heading. In producing the CDS for this extensive temporary works, TWBN's temporary works designer, OTB, proposed an alternative to this traditional solution. On Contract award, TWBN pursued this SCL option.

EXISTING ASSETS

As noted above, the site was particularly constrained, the overbridges:

A. Pass over and break into the west bound Central Line platform tunnel. This is 21ft 2½ inch (6,464mm), 12 segment cast iron lined tunnel constructed in 1908.
B. Pass within 1.5m under the existing Victorian brick lined mid level sewer which was constructed circa 1880 and consists 6½ft (1,981mm), three ring (350mm) thick engineering bricks.
C. Have only 3m lateral clearance to a branch of the Mail Rail Tunnel. This is a 9ft (2,743mm) ID cast iron, six segment tunnel constructed in 1915.

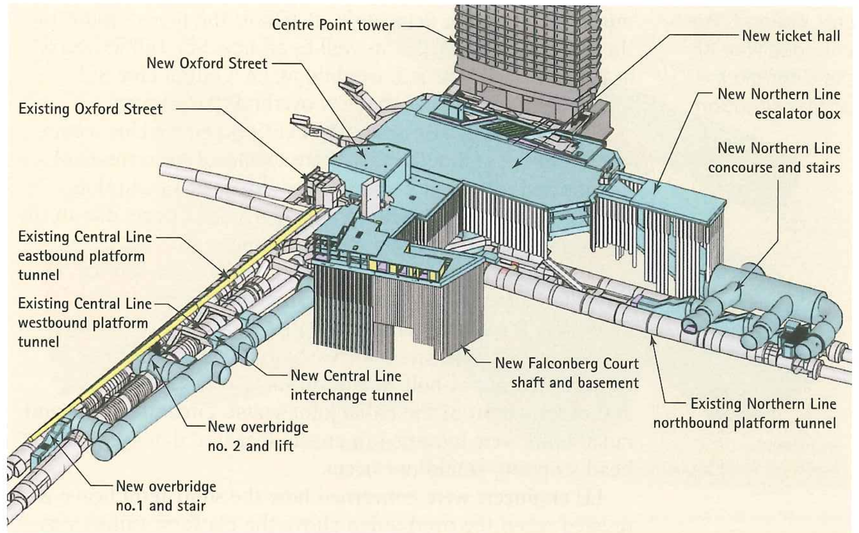
Early 20th century cast iron used in the platform tunnels is known to be extremely variable in quality and the asset assessments during the design phase were based on strength properties of old grade 10 cast iron as per LU standards and in accordance with industry practice. During initial construction phases, samples were taken and tested to show that the quality was marginally better than assumed.

Surveys were carried out prior to construction to ensure the lining was in adequate condition to resist the expected deformation and additional loading. The existing concrete cladding was broken back, and a detailed inspection was carried out of the condition of the cast iron lining. An "as-found" deflected profile was determined from the exposed sections of the platform rings.

Prior to work on the overbridges, significant assessment and protection works were developed and installed for the overlying Thames Water owned mid level sewer. The final sewer protection scheme required some 90 350mm diameter hollow steel tubes to be cored out from the adjacent cast iron lined Mail Rail tunnel. The tubes were installed into the ground between the sewer and the overbridge temporary works and fully grouted, thereby providing protective support to the sewer. The works in the Mail Rail Tunnel required the approval of the owner – the Royal Mail Group.

Close collaboration and engagement amongst TWBN, LU, Thames Water and RMG ensured that the proposed construction methodology for the overbridge was both challenged and robustly developed.

Early 20th century cast iron used in the platform tunnels is known to be **extremely variable** in quality and the asset assessments during the design phase were based on strength properties of old grade 10 cast iron as per LU standards



Above: Figure 1, TCRSU works shown in plan view

Opposite: LU's Central Line had to be operational throughout construction

PERMANENT WORKS

The permanent works are entirely encompassed within the primary SCL. Fabricated steel transfer beams have been installed onto the extrados of the platform tunnels where the crown of the tunnels have been removed, these pick up and transfer the hoop thrust around the opening and into reinforced concrete side saddles. The overlying soil load is resisted by a sprayed concrete roof that sits on the concrete side saddles.

The upper lobbies consist of traditional concrete encased steel square-works. The installation of the steel frames was made significantly easier because they were carried out within the temporary SCL shell.

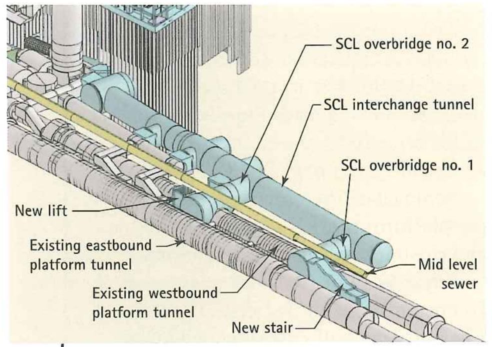
Removal of the crown segments of the platform tunnels required a full line closure and each was carried out during a 52 hour weekend possession. To ensure speed of installation, steel I-beams were half cast in concrete so they could be lowered into place and act as permanent formwork for the overbridge floor slab.

TEMPORARY WORKS

The sprayed concrete linings of both overbridges were designed to accommodate all aspects of the permanent works including concrete saddles; two steel transfer beams on each side of the WB platform tunnel; and the steelwork of the upper lobby structures. Of the two overbridges, overbridge two comprised the most onerous constraints since clearances and space were more restricted with the distance between Central Line platform tunnels only being 1.2m. Total overbridge length is approximately 17m with the largest cross section of $50m^2$ occurring at the upper lift lobby (approximately 7.8m in diameter). Two transitions in geometry were adopted to optimise the design, the first at the location of the southern transfer beam and start of cast-in-place concrete saddles and the second one at the location of northern transfer beam and start of upper lift lobby. The use of SCL allowed for such diametric changes with minimal construction implications and provided flexibility with regard to connections to existing underground structures. The end profile comprised a domed headwall at its upper part and the lower part formed around the presence of the Central Line eastbound platform tunnel.

Both SCL overbridges are located entirely within homogenous London Clay with a total soil overburden of 16.3m, equivalent to approximately two tunnel diameters. The typical geology across the site is 2.5m of made ground overlying approximately 4m of Terrace Gravels overlying approximately 30m of London Clay with the Lambeth Group below this.

The SCL had a typical design thickness of 300mm and was steel fibre reinforced. The thickness increased in the crown over the length where the Thames sewer advanced underneath the Thames sewer protection pipes. This was to remove the risk of any clay wedges falling off



Left: Figure 2, An enlarged view of the Central Line access situation

the under side of the pipes and ensured a safer working environment for the tunnelling personnel. At locations where the SCL was supported on the Central Line platform tunnels, a local elephant foot type thickening was adopted with a minimum width of 825mm sitting on the annulus grout of the tunnel. This reduced the stresses being transferred from the new structures to the existing cast iron lining and maintained levels within acceptable limits and factors of safety.

The design was based on concrete compressive cube strengths of minimum 35MPa after 28 days and an early compressive strength development following the J2 curve [1]. Residual flexural strengths of minimum class two [2] were specified.

The SCL structures were designed as temporary works only without long-term load carrying requirements. The permanent concrete works were designed and detailed to carry all loads for the structures' 120 year design life.

ANALYTICAL ASSESSMENT

Due to the criticality of ensuring adequate ground support, minimising ground movements and impacts to the platform tunnel linings, a three-dimensional finite element model (FEM) was set up.

The model provided loads and stresses for the SCL design and for the assessment of the interaction between new SCL structures and existing LU structures. Predicted deformation values for the existing structures related to individual construction stages could be retrieved from the model. This allowed comparison between predicted deformations and those actually encountered on site to be carried out. This increased confidence for all involved parties during construction.

ABAQUS v6.10 EF, a general purpose finite element software package, was used to perform the numerical analysis. LU's Central Line platform tunnels, the Royal Mail Mail Rail Tunnel and the Thames Water mid-level sewer were modelled. From the new works at TCRSU the pipes supporting the sewer were modelled as well as all new SCL tunnel works in the vicinity of the SCL overbridge, i.e. Central Line SCL interchange tunnel and the new overbridge structures.

For the impact assessment on existing Central Line assets, section forces and deflections were extracted from the FEM and plotted onto a moment - thrust envelope taking due account of existing condition and additional effects due to the "as-found" deflected profile of the tunnel.

Local bearing stresses were checked where the foot of the SCL shell sat on the platform tunnels; this resulted in increasing the foot to ensure adequate load spread. Further checks against local stress increases due to lining deflection were carried out at bolt-hole locations (i.e. flange cracking and deformation of the radial joint seats). Circumferential and radial bolts were loosened to ensure localised damage and bolt head stripping would not occur.

LU engineers were concerned how the short term heave was resisted when the overburden above the platform tunnel was removed. Calculations showed that the load could be safely transmitted along the length of the tunnel via the existing wrought iron circumferential bolts to a point where the soil overburden act to resist it again.

Additional assessments were carried out on the overlying bricklined mid level sewer to ensure deflections and associated strains were within those stipulated by Thames Water. Similar assessments were carried out to safeguard the Royal Mail Group owned Mail Rail tunnel.

CENTRAL LINE OVERBRIDGE CONSTRUCTION

Construction sequence

The primary driver for the sequencing of construction was to provide adequate ground support as quickly as possible, and thus minimise associated movement to the surrounding 3rd party assets. All aspects of the design focussed on achieving ground support quickly, and ensuring asset and personnel protection.

For the tunnel parts south of the Central Line westbound tunnel, a top heading and combined bench/invert excavation and support sequence was chosen. Typical standard advance lengths of 1m for top headings and 2m for combined bench/invert advances were used.

> Close collaboration between the JV amd client engineering directorate resulted in **savings of GBP 400,000 and seven weeks**

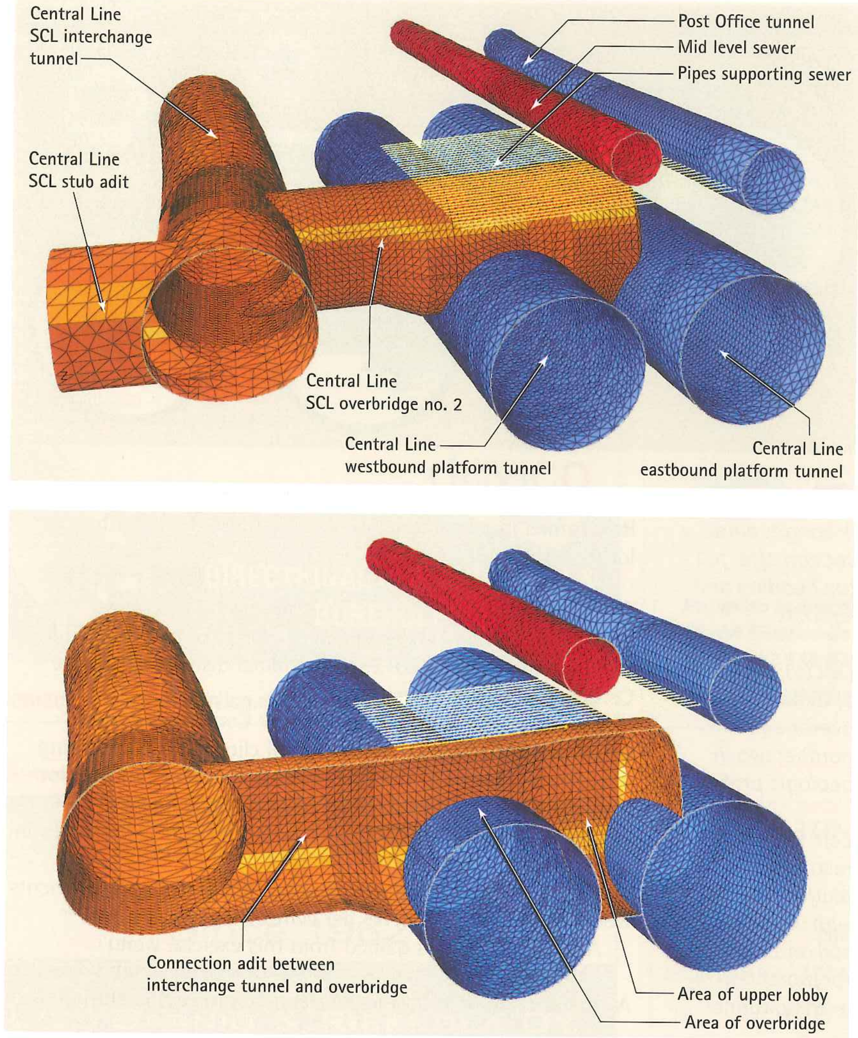
Full face (top heading only) 1m advances were carried out until the crown of the platform tunnels was passed. Following this the face was split into left and right hand side advances. Following completion of the remaining top headings, a partial SCL headwall was sprayed and a shaft type excavation was dropped between the platform tunnels in 1m advance steps.

Excavation was performed using a 2.5t excavator until space was too tight to allow the machine to enter. From there onwards a 1.5t rubber track excavator was used to complete the top heading excavation.

The 1m slices excavated downwards between the platform tunnels were hand mined.

Concrete spraying operations were performed using a mobile spraying robot until limited space restricted access and the Contractor switched to hand spraying.

Both SCL overbridge chambers were constructed between February 2012 and March 2012, each one taking three weeks.



Above: Figure 3, Central Line overbridge number two model

Mitigation and Contingency

LU approval of the scheme was dependant on TWBN putting in place a number of preventative measures to safeguard the platform tunnels, the Mid-Level Sewer, the Mail Rail Tunnel and buildings at street level. These measures included:

A. Maintaining a 500mm exclusion zone over the crown of the platform tunnels within which hand excavation was mandatory;
B. Continuous depth probing was carried out during construction to determine the exact location of the platform tunnels and to confirm the ground conditions;
C. Limiting the maximum size of plant and providing timber sleepers on the temporary backfill over the crown of the platform tunnel to spread the plant loading. The minimum protection measures on the outside of the exposed platform tunnel comprised 250mm backfill or unexcavated soil together with an appropriate cover;
D. Removal of the soil lying between theoretical crown extrados and horizontal pipes (minimum four steel pipes exposed). This avoided areas of loose ground and mitigated the risk of soil blocks falling;
E. Enlarged SCL footings where the temporary lining bears on the existing platform tunnels;
F. Bolt loosening in the platform tunnels local to the works to minimise risk of thread stripping and localised stress concentrations in the flanges of the tunnel segments;
G. The installation of wire mesh to the intrados of the platform tunnels to protect the public from the risk of loose render falling onto the platforms;
H. Daily RESS (required excavation and support) meetings attended by the contractor, the designer and LU where a review was undertaken of the automatic monitoring of the platform tunnels, the SCL convergence monitoring and deformations of the Mid-Level Sewer and Mail Rail Tunnel;
I. 24/7 attendance at the face by SCL inspectors employed by Dr. Sauer & Partners;
J. Continuous attendance of a watchman on the platforms during the works to check for distress in the tunnels during traffic hours;
K. Detailed visual inspections undertaken by TWBN during engineering hours to check the tunnel lining for signs of distress such as cracking, movement or tightening of bolts.

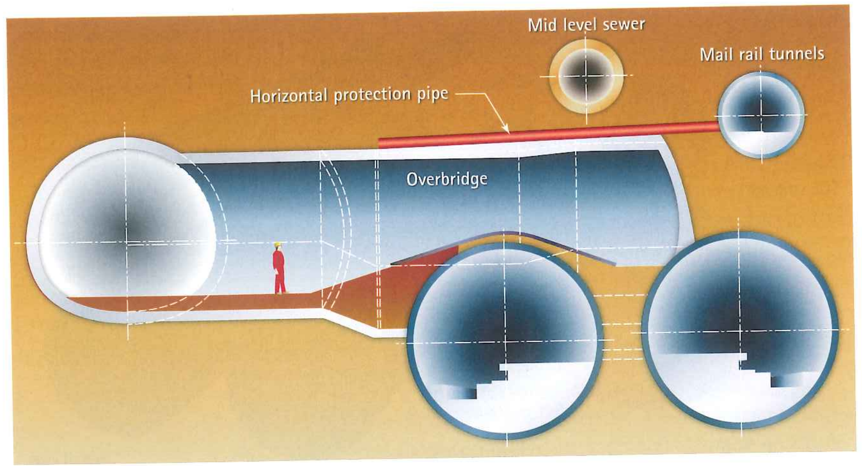
MONITORING

As part of the TCRSU construction works, a comprehensive monitoring system was set up on site and in the local vicinity. This included street and building monitoring prisms throughout the anticipated zone of influence and levelling studs over most of the LU infrastructure. A system of five point monitoring arrays was installed at 5m centres within the Central and Northern Line platform and running tunnels.

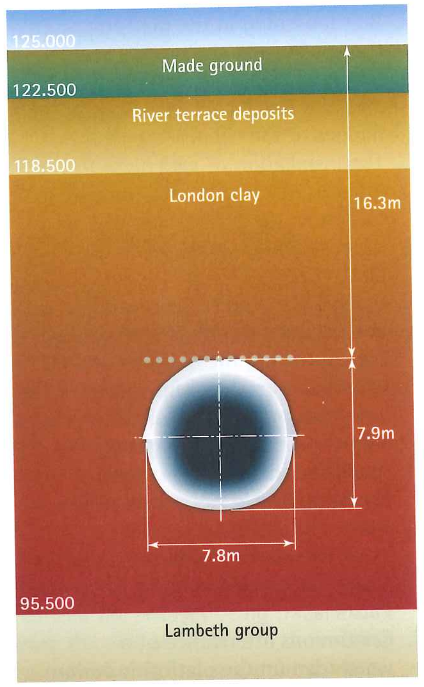
Due to the criticality of the existing assets and the innovative nature of the structure being designed, additional monitoring was proposed in and around each overbridge location, this included:

A. One five point prism array on the cast iron platform ring directly under each SCL footing
B. One five point prism array on the platform tunnel cast iron at the centre line of the overbridge
C. One five point array at the centre line of the overbridge on the east bound platform.

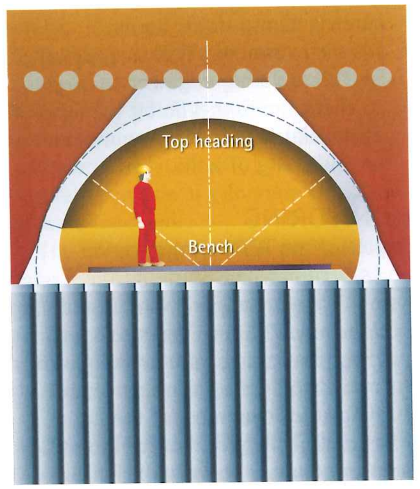
One of the main agenda items on the daily RESS meetings was the review of monitoring data. The deformation values of the Central Line platform tunnels were reviewed and compared to what the three-dimensional finite element



Above: Figure 4, Longitudinal section after full top heading and support



Left (top): Figure 5, Central Line overbridge number two in geologic profile



Left: Figure 6, SCL resting on top of platform tunnel with unexcavated soil and cover for protection of existing tunnel

model predicted for the corresponding construction progress. The encountered movement (direction and magnitude) compared well with the predicted ones. Crack surveys of the cast iron segments were performed each night in order to assess potential weak points in the platform tunnels.

5-point prism arrays and longitudinal electrolevels were also installed throughout the impacted zone of the RMG Mail Rail Tunnel.

Horizontal in-plane inclinometers were also placed into sub horizontal pipes that had been installed in the ground between the mid level sewer and primary lining to monitor the movement of the sewer. The Mail Rail Tunnel monitoring allowed these to be tied together and located in space.

CONCLUSION

Both the temporary and permanent works for both overbridges were completed early 2012 with minimal disturbance to the Central Line platform tunnels.

Close collaboration between the JV Contractor (Taylor-Woodrow-BAM-Nuttall) and eventual client (LU) engineering directorate resulted in the successful design and construction of the scheme achieving estimated project saving of approximately GBP 400,000 (USD 620,000) and seven weeks in construction programme.

As a testament to the engineering, the predicted movements were found to be within 15 per cent of those measured.

Additional benefits gained from this exercise were:

A. A reduction in Health and Safety risks to personnel due to:

- Minimising exposure to Hand Arm Vibration syndrome by adopting mechanised excavation;
- Minimising exposure of personnel to unsupported ground due to remote excavation and spraying;
- Reduced work in confined spaces during excavation (i.e. no timbering, installing walling);
- Constructing the permanent works in a relatively open excavation reducing risks associated with handling heavy steel and SGI items;

B. The increased speed of construction associated with the SCL option significantly de-risked the construction programme. The removal of the crown segments of the platform tunnel had to be carried out in pre-arranged line closures that are booked up to four years in advance. Missing these closures would have had significant ramifications to the overall construction programme. Adopting the SCL methodology gave sufficient benefit that one of the closures could be used for other construction activities.

C. The adoption of the sprayed concrete lined system means that a waterproofing system can be installed between the primary and secondary linings. This is not something that is achievable when adopting traditional multi-face hand mined excavations. The inclusion of this waterproofing increases the design life, durability and positively influences whole life costs of the structure through reduction in maintenance cost and requirements. The adoption of a spray applied waterproof membrane installed in the SCL tunnels was another first on the LU system for the TCRSU project

■ *All figures copyright TfL*

References

[1] **ÖvBB**, *Guideline Sprayed Concrete*, August 2006.
[2] **EFNARC**, *European Specification for Sprayed Concrete*, 1996.

To advertise here call Tom Willard on +44 20 7406 6599 or email *twillard@tunnelsonline.info*

EQUIPMENT

SPECIALIST PLANT
TUNNELLING EQUIPMENT HIRE & SUPPLY
Specialist Plant Associates Ltd
Agents for CIFA
Tel: +44 (0) 1234 781 882
Email: info@specialistplant.co.uk
www.specialistplant.co.uk

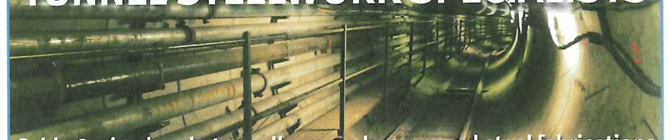
FUEL TANKS

WESTERN GLOBAL | ABBI
YOUR PERFECT REFUELLING PARTNER

T +44 (0) 1454 227 522
www.western-global.co.uk

FABRICATION

TUNNEL STEELWORK SPECIALISTS



Cable & pipe brackets, walkways, sleepers and steel fabrications
TRANSFORGE UK LTD
www.transforge.co.uk
+44 (0)1733 249260
info@transforge.co.uk

FIBRE REINFORCEMENT

MACCAFERRI
Engineering a Better Solution
Fibre reinforcement | Tunnel drainage | Fibreglass reinforcement
Self-drilling anchors | Steel arches | Ceramic linings
www.maccaferri.com

GROUND CONTROL

DYWIDAG-SYSTEMS INTERNATIONAL DSI
ALWAG SYSTEMS
GROUND CONTROL SOLUTIONS
DSI UNDERGROUND SYSTEMS INC.
www.dsi-tunneling.com

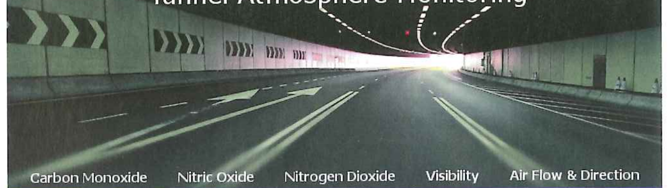
hw hoelscher dewatering
· dewatering
· groundwater control
· water treatment
www.hw-dewatering.com

MICROTUNNELLING

WHEN THE GOING GETS TOUGH...
...Iseki microtunnelling machines come smiling through!
Microtunnelling equipment - for hire or sale
ISEKI MICROTUNNELLING
Iseki Microtunnelling
Wellingborough UK
+44(0)1234 781166
www.isekimicro.com

MONITORING EQUIPMENT

Tunnel Atmosphere Monitoring



Carbon Monoxide | Nitric Oxide | Nitrogen Dioxide | Visibility | Air Flow & Direction
Low cost high precision tunnel sensors proven over 20 years
CODEL International Ltd
t: +44 (0) 1629 814351
e: sales@codel.co.uk
w: www.codel.co.uk
World leaders in tunnel atmosphere monitoring

PIPES and COUPLINGS

www.alvenius.com

Performance in Piping
Quick Connected Steel Pipe System - Corrosion resistant - Low weight - Impressive flow characteristics
ALVENIUS Performance in Piping

SVEBRA
LIGHTWEIGHT PIPING
Quick Coupling Pipes And Fittings
Strandvägen 25 I 686 30 Sunne, Sweden I T: + 46 565 689410 I F: + 46 565 711215
www.svebra.se

RAIL and ROLLING STOCK

Clayton
World Leading Locomotives & Haulage Solutions...
...for Mining, Tunnelling & Surface Transport
Clayton Equipment Ltd
www.claytonequipment.co.uk
Tel: +44 (0) 870 112 9191

Maschinen und Stahlbau MSD Dresden
For whatever reason you're tunnelling
MSD - your reliable partner for special tunnelling equipment.
www.msd-dresden.de

SEGMENT FITTINGS

TTC TECHNICAL TUNNELLING COMPONENTS
PLASTIC COMPONENTS FOR SEGMENT CONNECTION
BUILDING AND GROUTING SYSTEMS
WWW.TTCLTD.ORG
+44(0)1455 234401

SURVEYING and MONITORING

AMBERG TECHNOLOGIES
Tunnel Surveying
Tunnel Seismics
www.amberg.ch/at

TUNNELLING SUPPLIES

TA Tunnelling Accessories
EPDM GASKETS · PLASTIC SEGMENT FITTINGS · FOAMS & POLYMERS · HYDROPHYLIC RUBBER · BOLTS · PACKERS · LIFTING EQUIPMENT
BULLFLEX · SEALING STRIPS · SECONDARY SEALS · TBM LAUNCH SEALS · LUBRICANTS · ROLLING STOCK
+44 (0) 1424 854112
info@tunnellingaccessories.co.uk
www.tunnellingaccessories.co.uk

VENTILATION

SCHAUENBURG TUNNEL-VENTILATION GMBH
Flexible Ventilation Ducting
www.tunnel-ventilation.de
Phone: +49 208 8827610
Fax: +49 208 8827615

VENTILATION

AMCO PLASTICS LIMITED
Wire Reinforced & Layflat Tunnel Ducting
Tel: + 44 (0)1709 872574
Fax: + 44 (0)1709 879020
Email: info@amco-plastics.co.uk
www.amco-plastics.co.uk

VENTILATION DUCTING

VEC VENTILATION ENGINEERING COMPANY. (P) LIMITED
Tel :(+91-33) 22263882 / 22271303
Fax : (+91-33) 22262585
Email: ventduct@vsnl.com
WWW.DUCTSANDHOSES.COM

RECRUITMENT

Hunter Personnel
Recruiting For Your Industry
Specialists in Tunnelling and Infrastructure Recruitment
VIEW CURRENT VACANCIES ONLINE AT:
www.tunnelsandtunnelling.com
Contact: David Kellett
T: +44 (0) 1202 298322 E: tt@hunterpersonnel.com
For more information please go to: www.hunterpersonnel.com

RECRUITMENT

Due to the award of several new tunnelling contracts Kane Tunnelling Limited are actively seeking the following personnel:

kanetunnelling.com
KANE TUNNELLING LTD
CIVIL CONTRACTORS

TUNNEL MANAGER
Minimum of 10 years experience in either Drill and Blast Tunnels or TBM projects

MECHANICAL SUPERVISOR
Minimum of 10 years experience in either Drill and Blast Tunnels or TBM projects

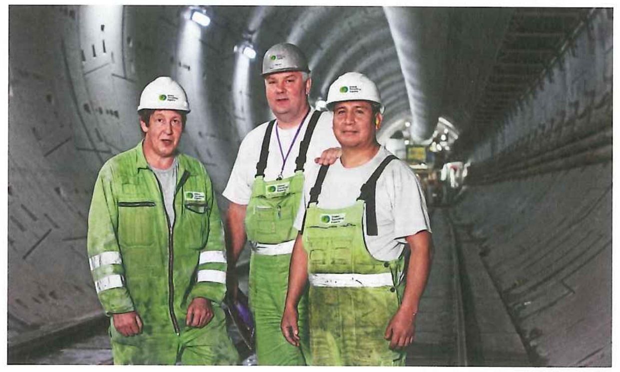
TBM PLC ELECTRICIAN
Minimum of 5 years experience

TBM ELECTRICIAN
Minimum of 5 years experience

- Must be available to commence work within three months
- Please send CV with expected remuneration package to:

ktlkane@btinternet.com

Global Tunnelling Experts. Bringing the best together.



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

Global Tunnelling Experts
+31 (0) 10 266 94 44
clients@global-tunnelling-experts.com
www.global-tunnelling-experts.com
The Netherlands | Germany | United Kingdom
Panama | Denmark | Australia

To advertise here call Tom Willard on +44 20 7406 6599 or email *twillard@tunnelsonline.info*

British Tunnelling Society — This is not the full list of British Tunnelling Society Corporate Members | To see a full list of all members visit: **www.britishtunnelling.org.uk**

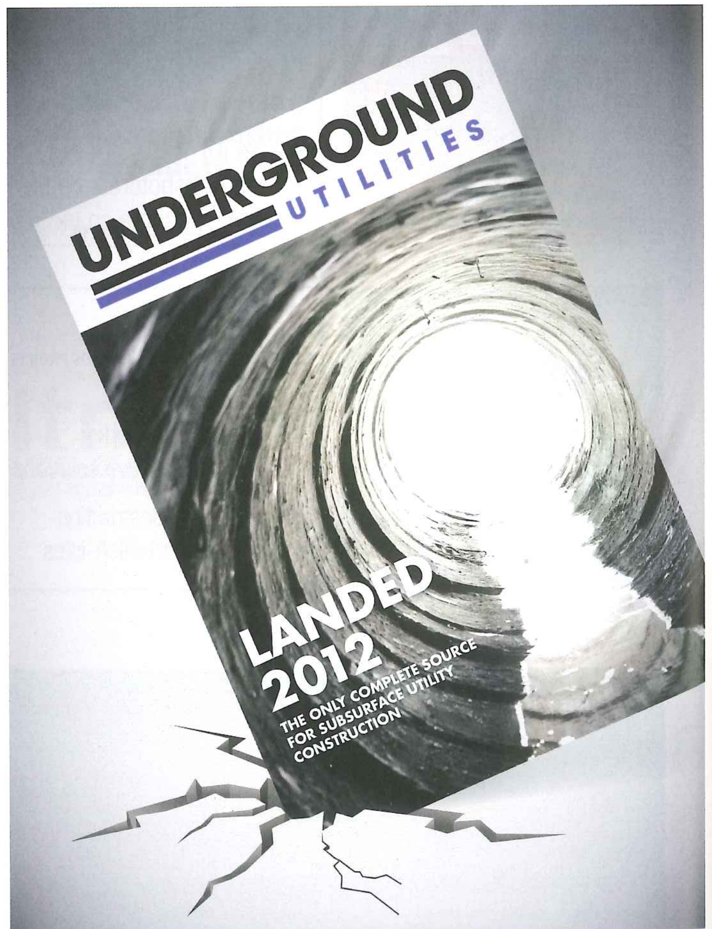
British Tunnelling Society

This is not the full list of British Tunnelling Society Corporate Members To see a full list of all members visit: **www.britishtunnelling.org.uk**

British Tunnelling Society — If you wish to become a British Tunnelling Society Corporate Member please email: **bts@britishtunnelling.org.uk**

If you wish to become a British Tunnelling Society Corporate Member please email: **bts@britishtunnelling.org.uk**

British Tunnelling Society



What's on

2013

World Tunnel Congress
31 May-7 June 2013
Geneva, Switzerland
The technical highlight of the conference calendar, the show includes WTC and the 39th ITA General Assembley.
wtc2013.ch

Tunnel Safety & Fire Protection
4-5 June 2013
Brisbane, Australia
This conference and networking event focuses on the need to optimise fire protection and safety for tunnel operators as tunnel developments boom across the Australasia region.
www.safetyintunnels.com

Construction Expo
5-8 June 2013
Sao Paulo, Brazil
Dedicated to both construction and infrastructure, this trade show will represent such sectors as materials, services and equipment providers for industries including roadways, airports, seaports, bridges and metros.
www.constructionexpo.com.br

Strait Crossings Conference
16-19 June 2013
Bergen, Norway
Organised by the Norwegian Public Roads Administration, the focus is on extreme crossings and new technology.
www.sc2013.no

RETC
23-26 June 2013
Washington D.C., USA
The Rapid Excavation and Tunnelling Conference is the largest North American tunnelling show. This year Washington plays host to the show and is expected to attract nearly 2,000 tunnellers from around the country and overseas. Tunnels will have a stand at the show so be sure to find us there.
www.retc.org

ISARC/WMC 2013
11-15 August 2013
Montreal, Quebec, Canada
The 30th International Symposium on Automation and Robotics in Construction, Minig & Petroleum Industries (ISARC) is being held in conjuction with the 23rd World Minig Congress (WMC). Both conferences will sponsor a joint trade show.
www.isarc2013.org
www.wmc-expo2013.org

18th ICSMGE
2-6 September 2013
Paris, France
The 18th International Conference on Soil Mechanics and Geotechnical Engineering (ICSMGE) will have a new format with the first two days devoted to plenary sessions and the following days devoted to discussion of papers and workshops from the committees.
www.issmge2013.org

Bauma Africa
18-21 September 2013
Johannesburgh, Africa
The massive construction show holds its first edition in Africa, focusing on all sectors of the construction industry.
www.bauma-africa.com

ExpoTunnel
17-19 October 2013
Bologna, Italy
The newly-established exhibition will also host the Italian Tunnelling Society congress entitled "Tunnelling and Underground Space for European Development."
www.expotunnel.it

Stuva Conference
27-29 November 2013
Stuttgart, Germany
The bi-annual conferency of the Stuva organisation heads to Stuttgart.

2014

CONEXPO
4-8 March 2014
Las Vegas, Nevada, USA
Held every three years, the exposition showcases the latest construction equipment, products, services and technologies. The show will be held at the Las Vegas convention centre.
www.conexpoconagg.com

ISTSS
12-14 March 2014
Marseille, France
The 6th International Symposium on Tunnel Safety and Security will discuss current practice and emerging trends and research in the field of tunnel safety and security.
www.istss.se

Samoter
8-11 May 2014
Verona, Italy
Trade show dedicated to earth moving, site and construction machinery held every three years.
www.smaoter.it

World Tunnel Congress
9-15 May 2014
Iguassu Falls, Brazil
The show includes WTC and the 40th ITA General Assembley.
www.wtc2014.com.br

British Tunnelling Society

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

Gotthard Base Tunnel
20 June 2013
After 10 years of tunneling, the two main breakthroughs were celebrated on 15.10.2010 in the eastern running tunnel and on 23.03.2011 in the western running tunnel, completing the two main tunnels of the 27 km long Bodio and Faido section. This report is presented by Rainer Rengshausen of Hochtief.

Thames Tideway Tunnels
19 September 2013
The presentation will include background on the sewage problems and the proposed solution; an update on the project development and design for tender; progress on the development consent application; an outline of the technical challenges faced; the proposed delivery route for the construction; and the latest situation on procurement

London Underground turns 150
23 October 2013
A special presentation in honour of the 150th anniversary of LU operations.

Contact us

Jon Young

Alex Conacher

Nicole Robinson

Jim Moore

Head Office

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

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

www.tunnelsonline.info
editor@tunnelsonline.info

Editorial

Editor
Jon Young
Tel: +44 20 7406 6622
jyoung@tunnelsonline.info

Deputy Editor
Alex Conacher
Tel: +44 20 7406 6616
aconacher@tunnelsonline.info

Americas Editor
Nicole Robinson
Tel: +1 612 940 2780
nrobinson@tunnelsonline.info

Regular Contributors
Maurice Jones, Adrian Greenman, Bernadette Ballantyne, Partick Reynolds, Rhian Owen

Production

Design/Editorial Production
David Cooper

Production Controller
Loraine Lee
Tel: +44 20 8269 7799
Fax: +44 20 8269 7840
llee@progressivemediagroup.com

Technical Illustrator
Nick Stenning

Sales

Head of Sales
Jim Moore
Tel: +44 20 7406 6584
jmoore@tunnelsonline.info

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

Classified & Recruitment
Tom Willard
Tel: +44 20 7406 6599
twillard@tunnelsonline.info

Subscriptions & Reprints

Subscription prices for 12 (24) months:
Mailed anywhere in Europe €262.50 (€459),
USA & Canada $258 ($258), UK £110 (£188),
Rest of the world $316 ($553).
Send subscription and back issue queries to *Tunnels* Customer Services:
cs@progressivemediagroup.com

Tel: +44 (0) 845 073 9607 (local rate)
Fax: +44 (0) 208 269 7277
subscriptions@progressivemediagroup.com
Tunnels Subscriptions,
World Market Intelligence,
Progressive House, 2 Maidstone Road,
Foots Cray, Sidcup, DA14 5HZ.
Subscribe online at *www.buythatmag.com*

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

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

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

Tunnels International ISSN 1369-3999 is published monthly by Global Trade Media, John Carpenter House, John Carpenter Street, London EC4Y 0AN, UK. The 2012 US annual subscription price is $ 226 Airfreight and mailing in the USA by agent named Air Business, C/O WorldNet Shipping Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, New York NY11434 USA. Periodicals postage pending at Jamaica NY 11431.

US Postmaster: Send address changes to Hotel Management International C/O Air Business, C/O WorldNet Shipping Inc, 156-15, 146th Avenue, 2nd Floor, Jamaica, New York NY 11434 USA.

Subscription records are maintained at Global Trade Media, John Carpenter House, John Carpenter Street, London EC4Y 0AN, UK. Air Business Ltd is acting as our mailing agent.

abc LinkedIn redr uk