INTERNATIONAL EDITION
April 2013

Tunnels AND TUNNELLING

PRAGUE METRO

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AN OPEN LETTER TO THE U.S. CONGRESS

DEAR ELECTED officials, or the interns who open their mail, while I have no direct affiliation with the organisers, I'm going to go out on a limb, here, and invite you to RETC, the Rapid Excavation Technology Conference, which is being held in your neighbourhood this June. I'm sure they won't mind.

Many of you seem to be under the impression that building new infrastructure is something similar to lighting a pile of money on fire, or that raising taxes to spend on such a project will cripple our nation's economy.

Please, stop by, and talk to any number of equipment companies driving innovation in tunnelling and wider underground construction.

Not only do these manufacturers find new ways to build tunnels safer, faster and at even less expense than they already have done, they also employ engineers, mechanics and drivers, not to mention other support staff in office, while working on a tunnel project.

Paychecks are likely to be used for groceries, mortgage payments, rent, other general living expenses that support the economy, and the occasional luxury splurge.

I have no solid statistics to hand, but it's highly unlikely many are hiding their wages or outrageous bonuses in an off-shore bank account, or another tax haven like your friends on Wall Street.

Multiply that by the companies that design and offer consulting services; the contractors; ancillary firms selling basic construction equipment, trucking services and more.

www.tunnelsonline.info

A world of information fully archived and searchable at the click of a mouse

Nicole Robinson
Americas Editor

Now, credit where credit is due, many cities and states have moved forward with their infrastructure and tunnel projects. There will be plenty of opportunities to learn about successful projects local and abroad. It's a great way to further your knowledge beyond donning a hardhat on site for a 15-minute photo op.

Looking at potential infrastructure in the US from upgrading sewers to high speed rail, if an elected official sees a reason not to move forward with a specific project, let's make sure it's for the right reasons.

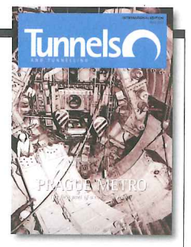
The pageantry of shutting down an important investment in American labour and innovation without being properly informed is no less foolish than an emperor's march in the nude.

According to the US Department of Transportation, in 2011, Americans 'stuck in traffic' wasted more than USD 120bn in accumulated time and fuel. That's one way to 'grow the economy'. Though this is probably not your constituents' first choice for how to do it.

Those constituents who have jobs, that is.

Sincerely, Nicole Robinson

Cover
The Prague Metro's construction has spanned half a century and seen sweeping political changes



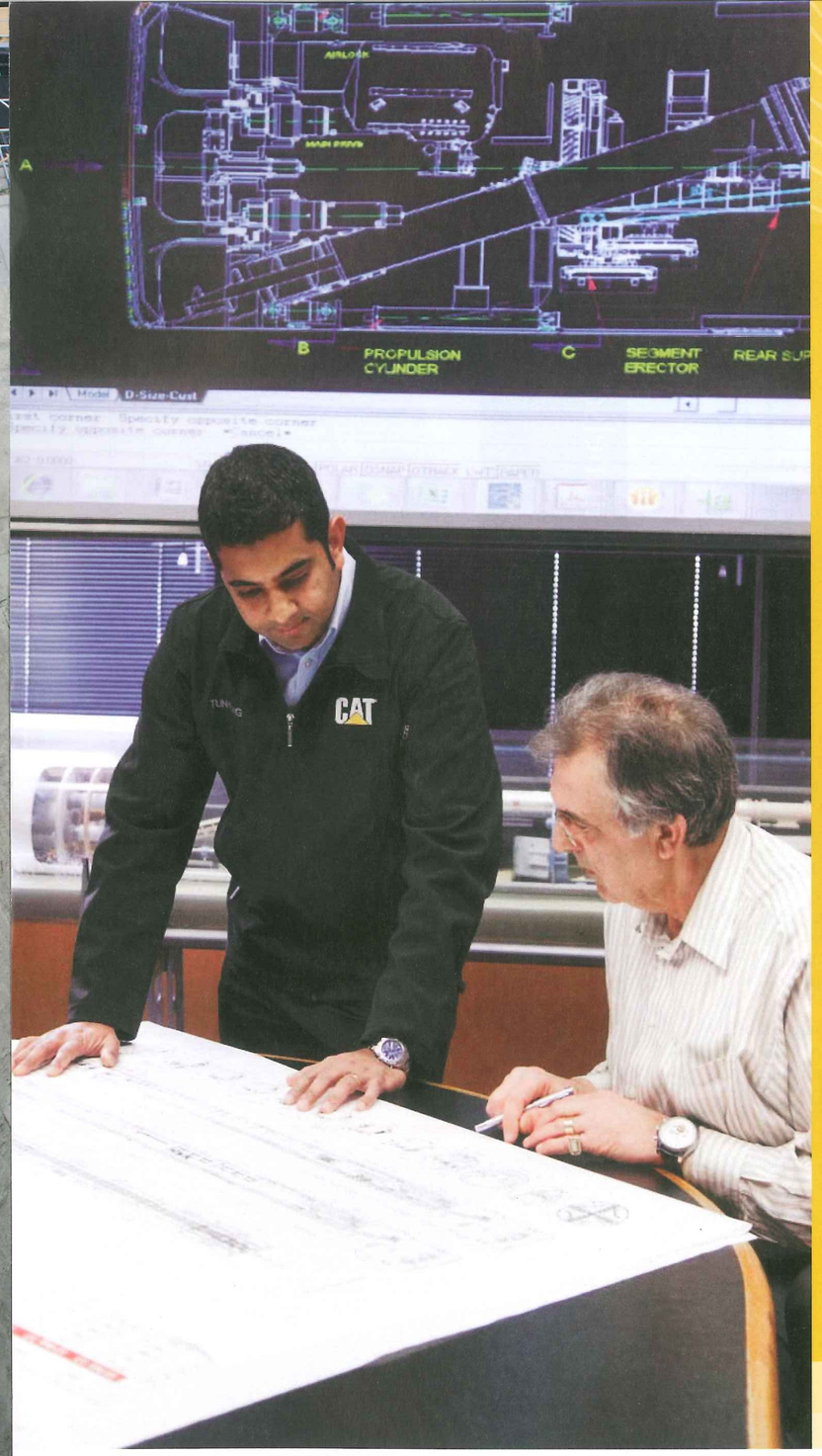
Next issue
Tunnels looks to an Australasian tunnelling market that still reels from bankrupt operating clients and project overspends. Nevertheless, a booming mining industry bouys a dynamic community that cries out for infrastructure. Modelling is a focus

This month...

10 YEARS AGO
International Tunnelling Association (ITA) president Andre Assis tells Tunnels that an important recent focus of the ITA has come in the wake of the high profile Alpine tunnel fires. Aside from the hard work put into technical solutions and safeguards, simply protecting the image of tunnels from negative public opinion has been key. Underground structures are a means to improve the very living conditions of people around the world.

20 YEARS AGO
A controversial tunnelling contract to divert a river for hydropower in northern Greece looks like it will go ahead. The winning bid is expected to be the TayEuro JV, headed by Taylor Woodrow. Final negotiations just had to iron out a few details. The River Acheloos Diversion would redirect the river into the Pindos Mountains.

40 YEARS AGO
The current expansion programme for the Madrid Metro envisages the construction of 55km of new line over a 12-year period. The first 22.2km should be completed by 1974. The new network, when completed in 1980, will effectively solve Madrid's commuter problem as no one will live more than 400m from a station.



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In this issue

The Prague Metro's construction spans half a century

News

7 *News*
The latest project updates and corporate moves around the world

16 *Bigger picture*
This month's photo worth a thousand words in tunnelling

Central and Eastern Europe

19 *Overview*
The European tunnelling industry prepares for Bauma and Brenner

22 *Prague Metro history*
The Czech capital's tunnel history is lit up in this comprehensive look

Technical

29 *Winery waterproofing*
A heady case study as fermentation caves survive vineyard operations

33 *Waterproofing cases*
Watertightness by polymer modification. A study of two succesful projects

39 *Double deck blasting*
A new style of blasting provides double the traditional advance

Insight

43 *Mining vehicles*
Tunnels looks at what is available from our sister industry in terms of loading, hauling and dumping

48 *Client TBM procurement*
Delving into the alternative to contractor procurement and the implications of the decision

BTS

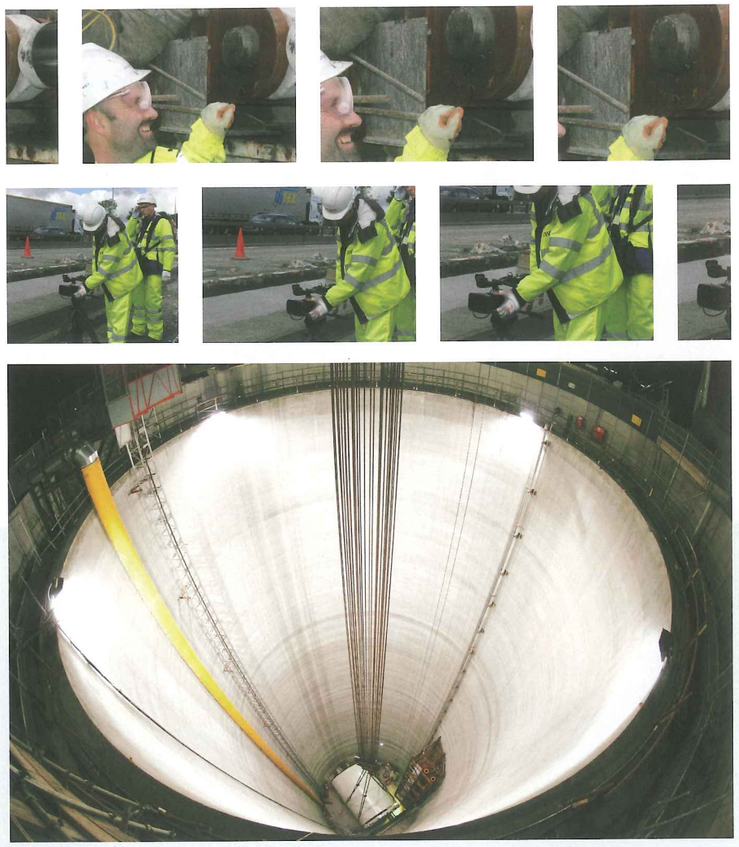
55 *URUP*
The shaftless TBM drive is presented to a packed meeting by Obayashi

Contributors

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

Vaclav Soukup
Vaclav is director of Metrostav's Division Five, the arm of the contractor that specialises in underground construction

Jodie Satterthwaite
Jodie is an experienced technical journalist specialising in the construction, architecture and design sectors



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News briefs

GERMANY

Bank robbers dug a 30m tunnel into the safe deposit room of a Berlin bank and escaped, setting a fire as they left to cover their tracks. The tunnel led from an underground garage into the bank's safe deposit room.

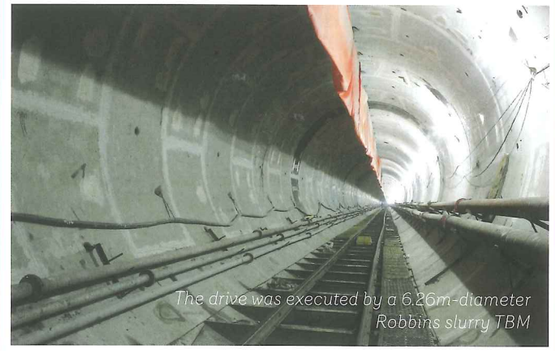
UK

Maidenhead-headquartered company Costain is increasing its activities in the Arabian Gulf as the company expands the range of services it offers in the region, it announced last month. Costain has provided services to the oil and gas industries of Abu Dhabi for more than 30 years but hopes to promote its consultancy expertise.

QATAR

Work on three metro rail stations, in Msheireb, Al Rayyan and behind the Qatar National Museum, is expected to begin shortly as part of the Qatar Integrated Railway project. These, along with two other stations in Doha and its outskirts, are among the 47 stations planned under the rail project, which covers four metro lines, tram routes, a high-speed line and dedicated freight railways.

TBM EMERGES FROM BELOW ZHANJIANG BAY



The drive was executed by a 6.26m-diameter Robbins slurry TBM

China A 6.26m Robbins slurry TBM excavated the Zhanjiang Bay Sub-Sea Tunnel at the end of 2012, the company announced late last month. The tunnel, which runs 56m below water level, is expected to become operational in March this year.

The 2.7km long conduit, constructed by contractor Guangdong No. 2 Hydropower Engineering Co required the use of a slurry machine to excavate under six bars of water pressure in Zhanjiang Bay. The TBM, supplied and assembled by Robbins with components and engineering from Mitsubishi Heavy Industries Mechatronics Systems, (MHI-MS), was launched in September 2011, the company stated. The TBM excavated up to 27m per day.

"The cutterhead design, layout of the cutters and injection ports were the most important design factors in completing this tunnel project," said Qinghua Shi, chief project engineer for the contractor.

The machine featured a smooth flow cutterhead to allow for easier removal of stones and boulders while avoiding clogging at the face. The mixed ground machine utilised interchangeable knife-edge bits that could be switched out for disc cutters in geology that included abrasive sand, gravel, and silt. The design approach for mixed face conditions is consistent with the Robbins design for mixed face EPB-type machines, the company stated.

"Throughout the project, I felt there were no significant problems that happened on the machine," added Shi. "I am happy that we could operate the machine properly. There were no cutters that needed to be changed, even though this was a long tunnel excavation project. The launch and breakthrough also went very smoothly indeed."

Mass Rapid Transit project development may begin next month

Indonesia Jakarta Governor Joko Widodo said his administration will begin development of the capital's mass rapid transit (MRT) system next month, stressing the urgency of getting the long-delayed project underway.

"I don't want us to back down. My goal is for all administrative matters to be completed by the end of this month so in March the development of MRT can start," he said on 20 February.

To support the plan, Joko said he would establish a study team, to include Jakarta citizens, in an effort to build support for the project. He acknowledged that there were still problems with the plan, which the team would seek to address.

"There will be an evaluation and study team for the project that involves the public, so that everyone will accept it and have a sense of belonging to it. We don't want our project to have a negative impact on people," the former mayor of Solo said after a public hearing on the MRT at the City Hall.

Residents of the Fatmawati area in South Jakarta who attended the meeting voiced their objections to the MRT project, with some expressing concerns that the development, which would pass through their neighborhood, gave rise to environmental problems. Rully Daniel, a citizen who lives in the Panglima Polim area of South Jakarta, urged the administration to construct all MRT lanes underground.

"Elevated lanes would only mess up the tidiness of the South Jakarta area," Daniel said.

In response, Joko said it was not possible to have all the lines underground, as subway development involved three times the cost of elevated tracks.

Earlier this year, the Jakarta administration and the central government reached a deal on the cost-sharing structure for the MRT's initial IDR 15.7tn (USD 1.63bn) tab.

The first phase of the project, a line from Lebak Bulus to the Hotel Indonesia traffic circle, will run 15.2km and is expected to be in operation by late 2016. A second phase, running 8.1km from the Hotel Indonesia to Kampung Bandan in North Jakarta, is expected to follow in 2018. Like the first TransJakarta busway corridor, the MRT's north-south line will cut through the city's key business district along Jalan Sudirman and Jalan Thamrin. But unlike the busway, the MRT will not take up an entire lane of existing roadway. Instead, the line will run on a combination of elevated and underground tracks in order to avoid disrupting traffic.

OMAN RAILWAY PROJECT ENVISIONS 6KM OF TUNNELS

Oman Massive lengths of rail tunnels, viaducts, rail bridges and wadi bridges will account for a significant chunk of the estimated OMN 6bn cost of the Oman National Railway Project.

As many as nine rail tunnels, extending a total estimated distance of 6km, are envisaged at key locations across the 1,061km length of the national railway network during phase one of its implementation.

A tender floated by the government last month inviting bids for a contract to undertake the preliminary design of the rail network has elicited strong interest from local and international engineering consultancy firms.

More than a dozen companies have so far collected tender documents indicating their initial interest in participating in the bid. The list includes Mott MacDonald, Sener, Bonifica, DB International, Parsons, Yas Consulting Engineers, Dar Al Handasah, Consolidated Consultants, Al Manarah Engineering, Ehaf Consulting, Khatib & Alami, Hoehler & Partner, and INECO (Spain).

A key component of the consultant's brief is to undertake the preliminary design of the complete infrastructure and systems covering all segments of the rail project, while also securing the basis for the implementation of a fully operational railway system interoperable with the Gulf Cooperation Council (GCC) network.

Provisional assessments of the key infrastructure components of the national network underscore the sheer size of the civil works necessary to be undertaken by contractors during the implementation phase.

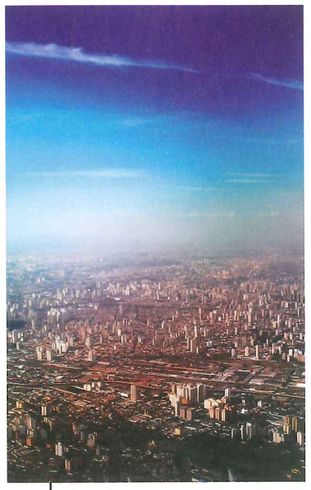
For instance, given the undulating terrain through which the alignment crosses in some parts of the country, gargantuan volumes of earth excavation and filling will have to be undertaken, say officials. Soil cutting and filling works along the length of the corridor is estimated in excess of a mammoth 210Mcu.m. More of half of this volume is required to be undertaken along the Muscat to Duqm and Misfah to Sinaw stretches.

Adding to the huge price tag of the project is the large number of rail tunnels and viaducts that will be required particularly along the northern and southeastern segments of the network. Of the estimated 6km of railway tunnels envisioned along the network, a third of this length will be required along the Sohar to Buraimi to Al Ain stretch.

In all, three major tunnels with a total combined length of 2.5km are proposed to be built along this corridor.

Officials also reckon the need for as many as 18 railway viaducts, some several kilometres long, to be built as part of the project's basic infrastructure. Viaducts are envisaged on the Sohar to Zuroub, Sohar to Al Hazm, Barka to Misfah, Misfah to Sinaw, and Sohar to Khatmat Malaha stretches.

Another major cost component is linked to the sheer length of rail and wadi bridges – estimated at 35km – in all that will be built as part of the rail project.



Sao Paulo skyline. The Brazilian city's metro project is one of the most ambitious

São Paulo metro contract awarded

Brazil A EUR 20M (USD 27M) contract to install auxiliary systems on São Paulo Metro's Line Five extension has been awarded. As part of a consortium, Alstom won the contract, the company stated. The expansion will start in 2013 with the first station, Adolfo Pinheiro, to be inaugurated by the end of the year.

The extension is due to be completed in 2015. Alstom will be responsible for supplying the main ventilation system for the stations and tunnels of the new line passage, which will be very important to ensure passenger comfort and safety, the company stated.

In service since 2002, Line Five has six stations linking Capao Redondo to Largo Treze and serves more than 22,000 passengers per hour. With the addition of 11 new stations, the line will have a total of 17 stations and will allow passengers to connect with two other lines; Line One at Santa Cruz station, and Line Two at Chácara Klabin Station.

Cross passage excavation completed on U-Link

Canada Construction is complete on University Link cross passage, including one in particular that had been underway 100ft (30.5m) below the surface since July last year.

Cross Passage 17, is one of 21 on the twin tunnel project connecting between downtown Seattle and Husky Stadium. The cross passages range between 18 to 24ft (5.5 to 7.3m) long and about 10ft (3m) in diameter.

"Building Cross Passage 17 became very challenging when the contractor [a joint venture of Traylor Brothers/ Frontier-Kemper] and encountered more water than originally anticipated. To stabilise the area for mining, it was necessary to remove water from the ground surrounding the tunnel to give crews a safe working environment," according to Sound Transit in a release on 19 February.

"For more than six months, generator-powered pumps removed water from soils around the tunnels. Today, Cross Passage 17 is nearly complete and work has turned to finishing the U-Link tunnels, including installing concrete duct banks, walkways, light rail tracks, power and signaling supply lines, tunnel lighting and communications."

Edinburgh unveils rail tunnel plan

Great Britain A tunnel is to be built beneath the Edinburgh bypass later this year, as work on the GBP 300M (USD 468M) Borders Railway gets under way, local media reported. The project will see a 40m tunnel excavated beneath the A760, eventually allowing a double track section of rail to. Up to 50,000 motorists a day will be diverted along a two-lane carriageway for the duration of the works.
The road will skirt the closed section of the bypass to allow workmen to excavate.

Work will begin in June 2013 while the temporary diversion route will come into effect from September. The project will be completed by May next year.

Crews in Japan began disassembling the 57.5ft (17.5m) diameter TBM that will excavate Seattle's Alaskan Way Viaduct bored tunnel replacement in early March, said the Washington State Department of Transportation (WSDOT). The transportation agency it expects the machine to arrive by sea before the end of the month, if the weather cooperates. Said to be the world's largest-diameter tunneling machine, the USD 80M TBM is owned by Seattle Tunnel Partners (STP), WSDOT's contractor for the project. The Hitachi Zosen TBM will be aboard the Jumbo Fairpartner in 41 pieces by mid-March.

Virginia tunnel project to begin with mass hire

USA SKW Constructors has announced it will hire as many as 100 direct employees at its Sparrows Point Shipyard and Industrial Park site as construction begins on huge reinforced concrete tubes and fans for tunnels in Hampton Roads, Virginia.

The company will also hire subcontractors that will hire additional carpenters, concrete finishers, mechanics, structural and reinforcing iron workers, surveyors, truck drivers and laborers. SKW Constructors, a joint venture of Skanska, Kiewit and Weeks, has already awarded subcontracts to 57 Baltimore metro area companies valued at nearly USD 5M.

Sal Taddeo, executive vice president of Skanska, added: "Sparrows Point is an ideal location for the manufacturing of materials for our Elizabeth River Tunnels project. We are looking forward to becoming part of a community with great talent and heart."

"This project is a huge boost in our efforts to bring new businesses and new jobs back to Sparrows Point. SKW has found a perfect location for heavy industrial construction and the timing couldn't be better for former steelworkers looking for new jobs that match their skills," said Kevin Kamenetz, Baltimore County executive.

Dominick Murray, Maryland Department of Business and Economic Development secretary, said: "This is great news for Maryland and for the Baltimore County.

"We look forward to working with SKW and our partners in Baltimore County to help match the many dedicated Sparrows Point workers with new jobs and opportunities."

MALAYSIA AND SINGAPORE TO DECIDE ON TUNNEL

Malaysia Malaysia and Singapore will decide this year on the preferred option for the Rapid Transit System (RTS) linking Johor Baru (southern Malaysia) and Singapore.

The options for the RTS rail network include building a bridge or an undersea tunnel across the Johor Straits.

Malaysian Foreign Minister Datuk Seri Anifah Aman said a study on the project was carried out in November last year and both countries have 12 months to decide on the findings.

Phase one of the joint engineering study (JES) was to identify the alignment and the station options with detailed assessment for the RTS.

Anifah was speaking to reporters before the two-day visit to Singapore of Malaysian Prime Minister Najib Tun Razak starting 18 February 2013. The retreat features Razak and his Singaporean counterpart Lee Hsien Loong, with the RTS being among the main topics of their discussion.

Singapore had earlier announced that its Thomson mass rapid transit (MRT) line would be opened in stages from 2019.

The 30km line will run through the north-south corridor of the island republic, starting in Woodlands, the area closest to Johor Baru via the Causeway. It will pass through industrial, residential and shopping districts before ending at Marina Bay.

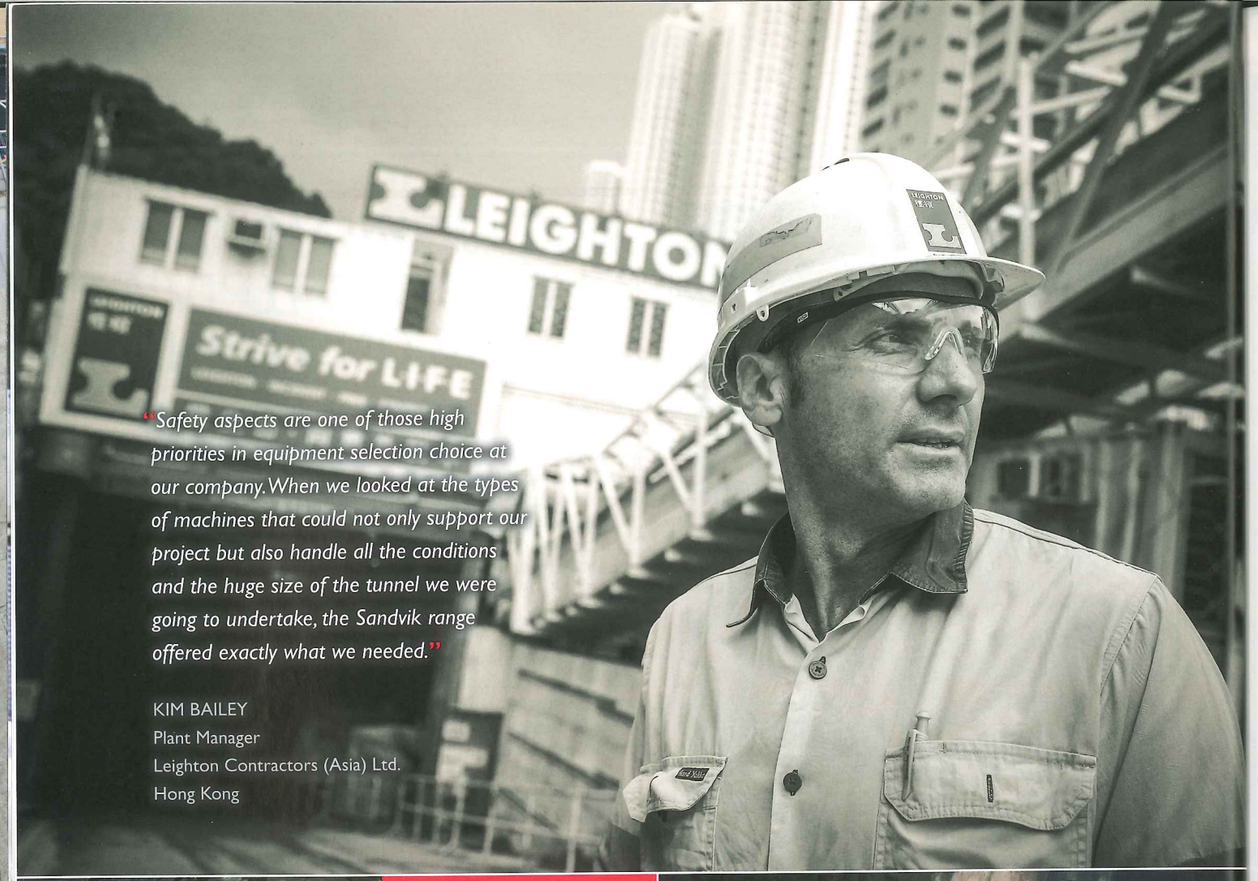
The entire SGD 18bn (USD 14.5bn) line will be completely underground and is expected to serve 400,000 commuters daily.

Tunnel escape foiled at west Indian jail

India Indian authorities say they have foiled an attempt by inmates accused of deadly bombings to tunnel their way out of a jail in the western state of Gujarat. The 18ft (5.4m) escape route was found in a part of Sabarmati Central Jail that houses prisoners on trial for bombings that killed 57 people in Ahmedabad in 2008, local news revealed.

Jail officials say the tunnel may have been dug with dinner plates and wood, although the tools have not yet been found. Inmates volunteered to work in the prison garden, where they dumped the sand they had extracted, officials told press.

The Minister of State for Home Rajnikant Patel has ordered an enquiry into the incident. An investigation was underway as *Tunnels* went to press.



"Safety aspects are one of those high priorities in equipment selection choice at our company. When we looked at the types of machines that could not only support our project but also handle all the conditions and the huge size of the tunnel we were going to undertake, the Sandvik range offered exactly what we needed."

KIM BAILEY
Plant Manager
Leighton Contractors (Asia) Ltd.
Hong Kong

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Jeddah tunnel opens

Saudi Aabia One of the most important tunnel projects in Jeddah at the busy Madinah Road and Sari Street intersection opened on Monday, 25 February 2013, municipality officials announced.

The project was delayed for nearly nine months and went over budget by more than SAR 10M (USD 2.7M).

The project, with an estimated cost of SAR 104.3M (USD 27.8M), started on 14 May 2010, and was scheduled for completion on 24 April 2012.

However, the contractor determined that the presence of underground water pipelines and telephone cables would add to the construction costs.

A new completion date for the tunnel was scheduled for 7 December 2012, but the project was further delayed.

The project was inspected by Prince Mansour bin Miteb bin Abdulaziz, minister of Municipal and Rural Affairs. He extended the deadline for the completion of the project for another 75 days, which pushed the new completion date to 6 March 2013.

Monday's opening puts the completion date almost two weeks ahead of the last given date.

The telephone exchange for the Salamah area was one of the major obstacles blocking completion. In addition, the original estimates for the number of underground telephone cables was 14,000 pairs, but the excavation contractor discovered 54,500 pairs, which were moved during the course of construction.

Later, additional designs, and the construction of flood and storm water facilities added to further delays.

The original cost of SAR 94M (USD 25M) was increased to SAR 104.3M. The work was executed by Safa Contracting Company while Parsons was chosen as the consulting firm for the tunnel project.

An attractive pathway with red color mosaic tiles was built along the tunnel in order to facilitate pedestrians.

UK Government sells Staffordshire tunnel

Great Britain The UK's Department for Transport has placed a discused Victorian railway tunnel in Staffordshire, the Harecastle Railway Tunnel, on the market for sale. The approximately 1 mile (1.6km)-long tunnel has been out of use for a period of more than 40 years.

The tunnel is listed for sale on the 'Find me some Government space' website, which has been launched in order to assist in the disposal of vacant, Government-owned property and land. The tunnel property listing has given the description of the plot as as 13.8m2 of 'surplus land' and includes the Harecastle tunnel and associated land.

Only public bodies that agree to take up strict maintenance obligations will be considered.

North Staffordshire Railway built the tunnel in 1848 and it remained in continued use for more than 100 years.

Illinois village residents face USD 74M storm water projects

USA Construction of a new storm water sewer system in Winnetka, Illinois, could cost as much as USD 74M and could be partly paid for by residents based on the amount of storm water runoff created on their property, a local newspaper stated earlier this week. The scope of the proposed storm water project to relieve chronic flooding problems is still being defined.

Preliminary figures highlight it would cost Winnetka some USD 48.2M to build a storm water drainage system, but this figure would decrease if the village decided to move ahead on a less comprehensive storm water management system. However, this does not include the cost of financing the project. During a recent 'rate and fee analysis workshop' village staff and consultants told trustees that the total cost of the project would cost more than USD 74M when including interest paid on bonds over a 30-year term, the local paper stated.

The proposed Winnetka sewer water project would be the most expensive storm water utility in the country on a per resident basis, the local reports revealed. The village is seeking residents' input on all proposal aspects.

TUNNELS AWARDS

The Tunnels Awards 2013 build on the immensely succesful 2011 showing as this bienniel event recognises the best of the industry

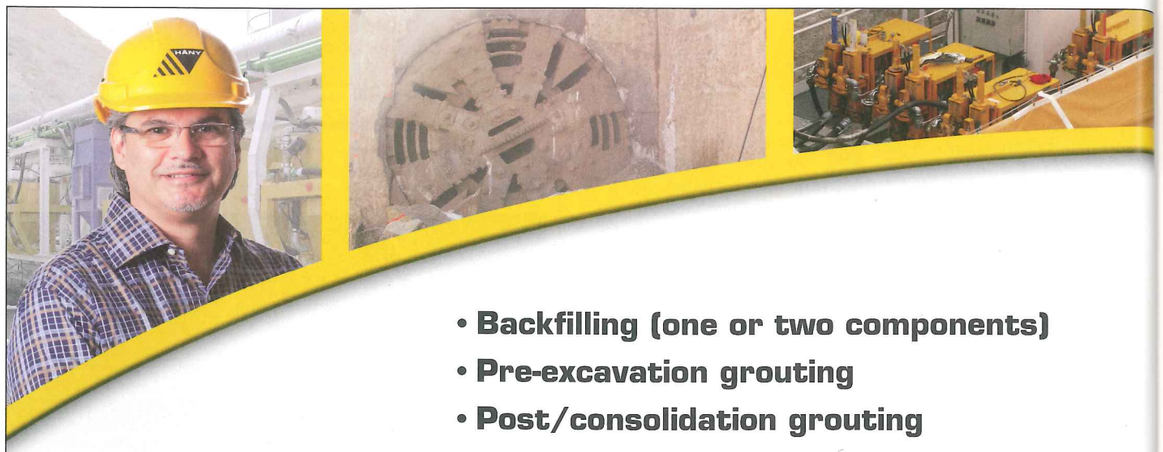
Awards Competition is heating up for the 2013 Tunnels and Tunnelling Awards as entries pour in from major projects around the world. The awards aim to identify and applaud those who go above and beyond to meet the testing demands of clients, budgets, schedule, geology and scope. The awards will once again be judged by a robust team of industry leaders and will be supported by the British Tunnelling Society. The deadline for entry is 1 July.

There are three categories each with a number of awards. In the Overcoming Adversity category, entrants will compete for the Endurance Award 'for completing a project in the face of numerous or persistent challenges'; the Tour de Force Award 'for successfully overcoming the single greatest challenge'; and the Foresight Award 'for the early identification and mitigation of a problem in design or construction'. The Overcoming Adversity category attracts entrants from the toughest projects.

The Sustainability category awards those who feed most back into the industry, and protect the natural world. The Investor in Tunnellers Award is arguably the most prestigeous as it champions the education of tunnellers. The Preservation Award recognises 'tunnelling with the lowest impact on the environment through design or construction methods'.

The Innovation category applauds developments in materials, equipment and instrumentation. Unlike other industry awards this category credits unusual deployments of existing technology and the proven use of new technologies.

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'



- **Backfilling (one or two components)**
- **Pre-excavation grouting**
- **Post/consolidation grouting**

- High-Shear Mixers up to 2500 litres
- Grout pumps up to 200 bar
- Pressure and flow recording systems
- Compact grout plants
- Bentonite modules for microtunnelling
- Fully automated grout plants
- Backfill systems for one or two component grouts

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Central bank rates

	Rate (%)
AUD	3.00
BRL	7.25
CAD	1.00
CHF	0.25
CNY	6.00
EUR	0.75
GBP	0.50
INR	7.75
JPY	0.10
NZD	2.50
USD	0.25

Rates are taken on the 12th of each month.

Share tracker

Company	January	February	Change (%)
Aecom (NYSE: ACM)	29.4	31.9	▲ 2.5 (8.50)
Atkins (LSE: ATK)	832	920.26	▲ 59.5 (7.7)
Balfour Beatty (LSE: BBY)	273.1	265.4	▲ 16.9 (5.8)
BASF Global (XETRA: BAS)	71.51	75.11	▲ 0.51 (0.7)
Bekaert (BSE: BEKB)	21.58	21.97	▲ 0.58 (2.6)
Bilfinger Berger (DUS: GBF)	76.77	81.82	▲ 5.05 (6.58)
Caterpillar (NYSE: CAT)	97.22	89.28	▼ 2.03 (2.1)
Costain Group (LSE: COST)	263.5	286.06	▲ 2.25 (0.9)
Ferrovial (MCE: FER)	11.32	12.6	▲ 1.28 (11.31)
Hindustan Construction Company (BOM: HCC)	17.2	15.6	▼ 1.7 (8.99)
Hochtief (XETRA: HOT)	48.69	54.99	▲ 2.47 (5.34)
Morgan Sindall (LSE: MGNS)	600.77	543	▼ 59.77 (11.05)
Sandvik (STO: SAND)	103.6	103.8	▲ 0.9 (0.86)
Shanghai Tunnel Engineering (SHA: 600820)	9.72	8.76	▼ 0.89 (10.07)
Strabag (LSE: STR)	19.62	18.74	▼ 0.26 (1.31)
URS Corporation (NYSE: URS)	42.4	45.17	▲ 1.77 (4.36)
Vinci (EPA: DG)	35.92	36.49	▲ 1.18 (3.18)

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.

Aecom maintains presence in 145-strong ethical companies list

USA Aecom was named one of the world's most ethical companies. The announcement last month marked the third consecutive year the company had been recognised by the 'Ethisphere Institute'.

The distinction claims to reward companies that "demonstrate leadership in ethical behaviour by embracing ethical business practices that raise the standard for industry peers." An Aecom spokesman argued that this recognises the company's commitment to compliance practices, corporate social responsibility and ethical leadership.

Aecom chairman and CEO John Dionisio added, "[This] reflects the commitment of our employees around the world to foster a values-based culture with unwavering dedication to integrity in everything that we do. [...] We will continue to strive to be an industry leader in ethical standards."

Ethisphere is a research-based institute dedicated to the creation, advancement and sharing of best practices in business ethics, corporate social responsibility, anti-corruption and sustainability. This year – the seventh year Ethisphere has published the World's Most Ethical Companies list – a record number of nominations and applications were reviewed from companies in more than 100 countries and 36 industries. For 2013, 140 companies were named to the list.

Crossrail announces operations director and star apprentices

Great Britain Crossrail has appointed an operations director to oversee future services, the company announced last month. Howard Smith, who is currently chief operating officer Transport for London, is taking up the new position.

Smith led the GBP 1bn (USD 1.5bn) East London Line extension project as well as the development, launch and operation of London Overground and management of its operating concession, Crossrail stated.

"Howard Smith has significant and diverse railway experience having overseen the creation of London Overground and worked on DLR, national rail, London Underground and the successful 2012 Games," said Andrew Wolstenholme, Crossrail chief executive. "His knowledge of railway operations and the delivery of high-quality rail services in London and the southeast is unrivalled."

In addition, Crossrail gave special recognition to those of its apprentices it regarded as having made outstanding progress in the last year. The project client has employed 150 apprentices out of its target of 400.

Further Education & Skills Minister Matthew Hancock said: "I want to congratulate all the winners on their hard work and success. The stories I heard at the awards today really demonstrate that apprenticeships deliver for employers and individuals."

Oil price

110.3
February 2013

108.5
March 2013

Values are taken on 12th of each month.

JOHN LESLIE KEYS

Founding member and director of London Bridge Associates **John Keys** who though only 51 suffered a fatal heart attack while travelling on the Jubilee Line on Monday 14 January. John is survived by his wife, Alison, and two sons, James and Matthew

John Leslie Keys

JOHN KEYS graduated with a first class Honours degree in Mining Engineering from the Camborne School of Mines in 1982. He commenced work with Thyssen on site sinking shafts for the National Coal Board in Scotland and Yorkshire before moving into tunnelling on the Three Valleys project for Thames Water. He gained a large amount of varied experience on this project including wedgeblock linings, large and small diameter shaft sinking, compressed air tunnelling and ground freezing using liquid nitrogen.

He went back to the mining industry for his next piece of unique experience, which was the construction of the 220m deep, 3.85m diameter Betws shaft using the largest land based drilling rig in Europe employing reverse circulation and Blind Shaft drilling technology.

In 1986 John moved to Barrow-on-Soar where the task was the construction of two mine access tunnels through water bearing shales for the British Gypsum Mine. Believed to be the first use of the NATM in the UK, this set John on an interest he was to follow throughout the rest of his career.

He went on to work with the Hand Tunnels section of TML on the Channel Tunnel where his interest in NATM flourished with the extensive use of this technique in the underground development works at Shakespeare Cliff and the undersea crossover. Then came a spell with MT group on the difficult Storebaelt Tunnel in Denmark before he returned in the UK in 1993 to join Taylor Woodrow and the Costain Taylor Woodrow Joint venture at Contract 104 London Bridge Station on the Jubilee Line Extension. This was a complex warren of shafts and tunnels for the Jubilee Line and Northern Line stations beneath the mainline London Bridge Station. John again gravitated towards the NATM works (to become SCL works over the course of the contract) and the impressive cast iron work on the JL station and produced what is arguably the finest tunnelled station on the London Underground.

When he was appointed Project Manager on the Ramsgate Harbour Approach Road, John further demonstrated his impatience to embrace new techniques and unfamiliar technology and brought in the Perforex prevaulting system for the first time in the UK to drive this impressive tunnel. The project was also characterised by the use of a very integrated collaborative team and a well-satisfied client

The year 2000 saw the formation of London Bridge Associates (LBA). John was a founding member and major shareholder and then in recent years a director. He brought a tremendous breadth of experience and knowledge and made major contributions to projects such as the Dublin Port Tunnel, tenders including A303 Stonehenge, A3 Hindhead, Shepherds Bush Station, Combe Down Mines, Strood Tunnel Refurbishment, Kings Cross station Upgrade, Tottenham Court Road Station and Bond Street Station Upgrades.

He worked with the Balfour Beatty Costain JV in the planning and design phase of the ECI contract for the Stonehenge tunnel leading the construction planning input in the scheme development. The scheme did not go forward and he moved on to a further absorbing issue; risk management. The Joint Code of Practice for Risk Management on Tunnelling projects had been recently drafted by the BTS in conjunction with the ITG and needed experience and understanding to implement. John undertook Risk Reviews on a number of projects for the Insurance companies and advised contractors and designers on the compliance requirements.

Recently he had major input into the design and led the construction planning of the Victoria Station Upgrade with the designer and the LUL Bond Street Station Upgrade with the contractor.

He was a regular contributor on BTS courses, speaking and running exercises in risk and managed the Risk Management section of the Construction Management module of the MSc Tunnelling course at Warwick University. Though not a committee member he contributed to the sub group for the BS 6164 update and was a peer reviewer on the SCL Best Practice Working Group and the Nitrogen Oxide Working Group.

John will also be well remembered as a husband and father by his wife Alison, and sons James and Matthew of whom he was very proud. The BTS and LBA will miss his contribution; we will all miss his thirst for knowledge and learning.

■ *Bob Ibell, LBA*

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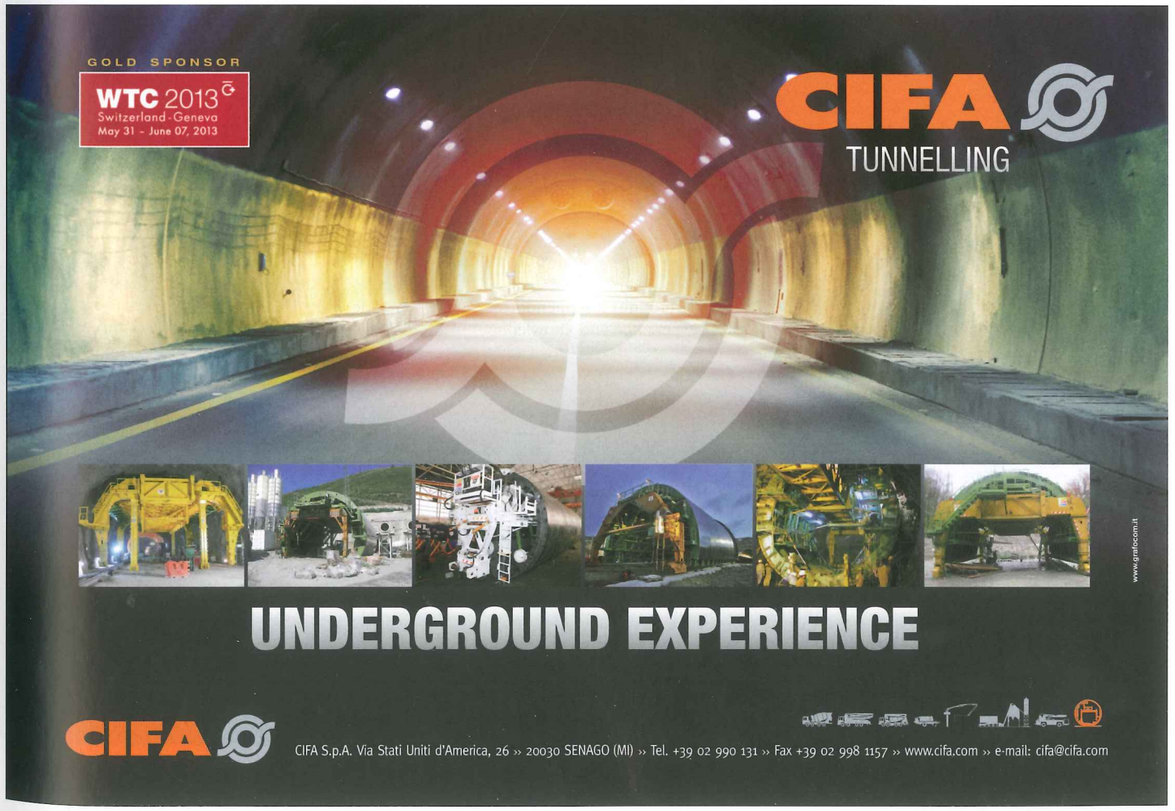

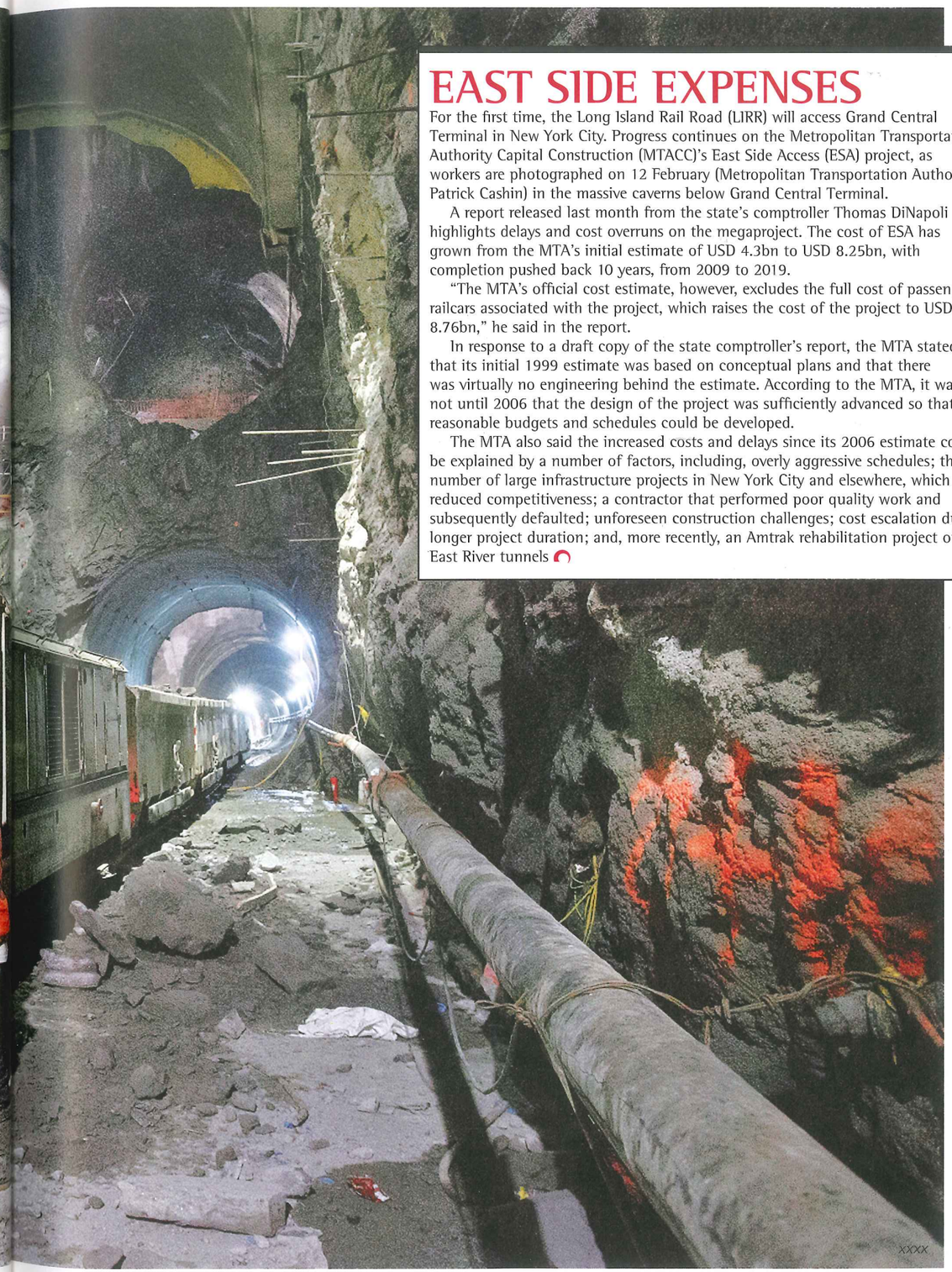

EAST SIDE EXPENSES

For the first time, the Long Island Rail Road (LIRR) will access Grand Central Terminal in New York City. Progress continues on the Metropolitan Transportation Authority Capital Construction (MTACC)'s East Side Access (ESA) project, as workers are photographed on 12 February (Metropolitan Transportation Authority / Patrick Cashin) in the massive caverns below Grand Central Terminal.

A report released last month from the state's comptroller Thomas DiNapoli highlights delays and cost overruns on the megaproject. The cost of ESA has grown from the MTA's initial estimate of USD 4.3bn to USD 8.25bn, with completion pushed back 10 years, from 2009 to 2019.

"The MTA's official cost estimate, however, excludes the full cost of passenger railcars associated with the project, which raises the cost of the project to USD 8.76bn," he said in the report.

In response to a draft copy of the state comptroller's report, the MTA stated that its initial 1999 estimate was based on conceptual plans and that there was virtually no engineering behind the estimate. According to the MTA, it was not until 2006 that the design of the project was sufficiently advanced so that reasonable budgets and schedules could be developed.

The MTA also said the increased costs and delays since its 2006 estimate could be explained by a number of factors, including, overly aggressive schedules; the number of large infrastructure projects in New York City and elsewhere, which reduced competitiveness; a contractor that performed poor quality work and subsequently defaulted; unforeseen construction challenges; cost escalation due to longer project duration; and, more recently, an Amtrak rehabilitation project of the East River tunnels

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 July 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*.
awards@tunnelsonline.info

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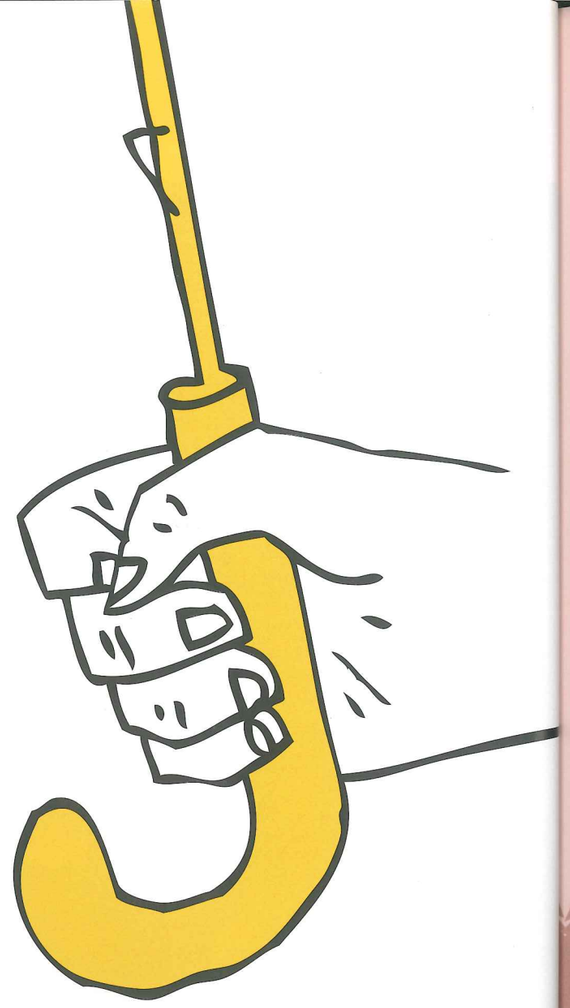

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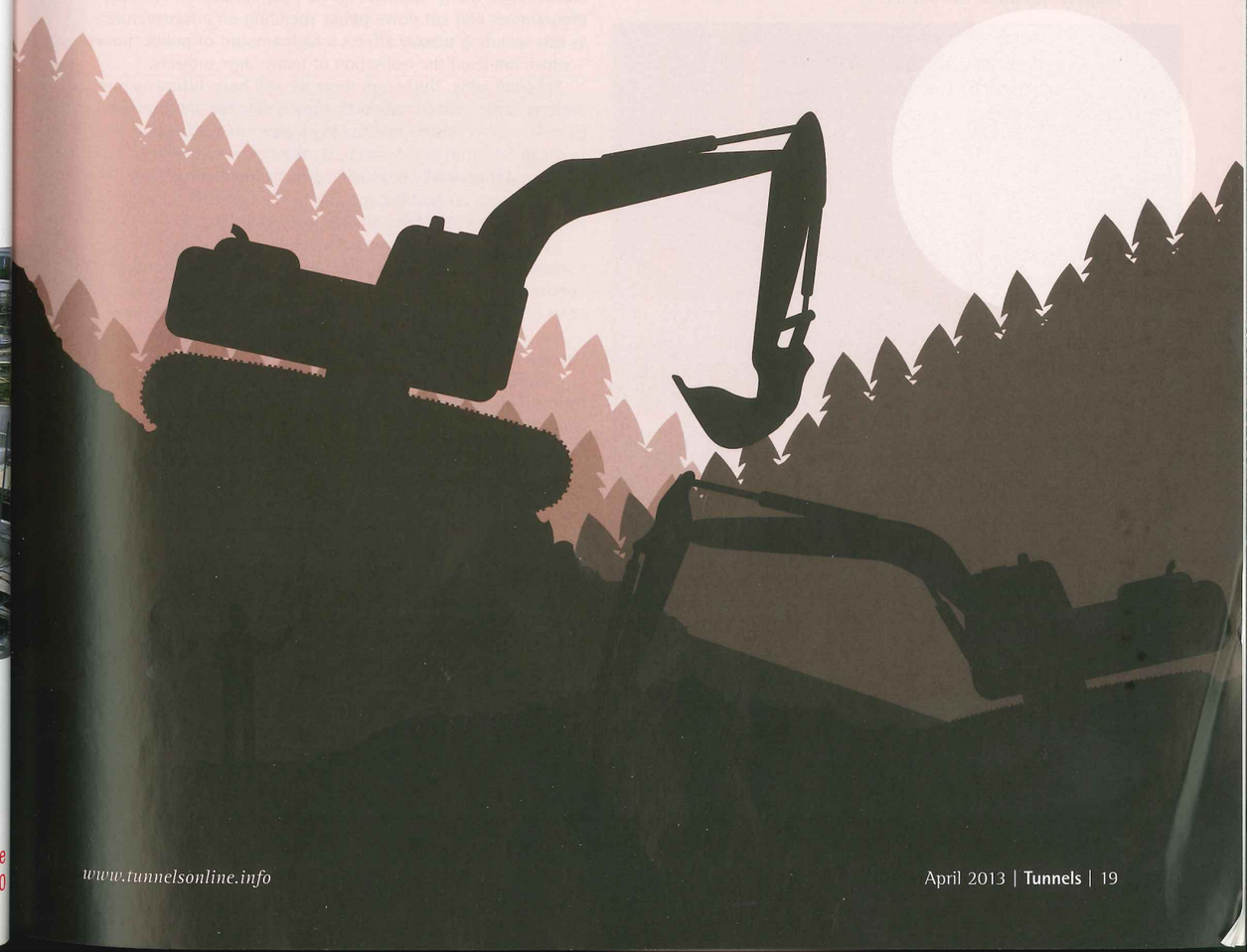
BACK TO BAUMA

Bauma in Munich, UC in Prague, and thoughts from the largest contractor in Central and Eastern Europe as *Tunnels* looks to the region in this focus

Edgar Schömig
Edgar is a member of the board and comes from a position as Zublin's tunnelling MD



AS THE tunnelling industry heads to Munich, Germany for the triennial Bauma tradeshow, Tunnels eyes Central and Eastern Europe for its regional focus. Here we publish the first portion of a three-part article by Ermin Stehlik and Vaclav Soukup of Metrostav on the construction history of the Prague Metro from its inception in 1966 to the present, and into the future. Stehlik and Soukup will be giving a keynote presentation based on the paper at UC Prague 2013 in the week following Bauma.

It's an exciting period for conferences, but business has been a mixed bag in the heart of continental Europe. Edgar Schömig, tunnelling manager and board member for Strabag tells *Tunnels*, "The building industry hopes for a stronger focus of governments and local authorities on the expansion of infrastructure. It would be highly desirable if there was more continuity and a shorter period of time between the planning of infrastructure measures and the actual implementation of the construction works.

"Some 90 per cent of tunnelling projects worldwide are put out to tender by the public sector. Thus, politics and parliamentary institutions naturally are the main drivers of public works. In recent times, many countries [in Europe] decided on austerity programmes and cut down public spending on infrastructure – as this spending usually affects a high amount of public money – which hindered the realisation of many large projects.

53
The length in kilometres of the longest transport tunnel in the world, the Gotthard Base Tunnel, which will be surpassed by the 54km Brenner

Koralm Tunnel statistics

- **Length:** 33km (KAT2 contract comprises the 20km main drive)
- **Main contractor:** Strabag/Jaeger integrated JV
- **Designer:** Geoconsult of Austria, Bernard of Austria, Lomarbi of Switzerland, Basler + Hofmann of Switzerland and IMM of Germany
- **Primary excavator:** 9.9m Aker Wirth TB 993 E/TS double shield
- **Segment design:** Zublin
- **Segment moulds:** Herrenknecht Formwork

See Tunnels International, August 2012, pp.33-34 for more.

Brenner Base Tunnel statistics

- Some 3.2km of investigation boreholes have been drilled
- The 64km-long tunnel will surpass Gotthard
- Total project cost: EUR 7.9bn (USD 10.3bn)
- Main tunnelling works to last until 2025
- Total excavated spoil of 17Mm3
- Planned diameter of 8m

Below: The tunnelling industry heads to Bauma Munich this month

Schömig adds, "Although there are still huge infrastructure projects to be realised within the next years, e.g. the Brenner Base Tunnel in Austria and the high-speed railway expansion between Stuttgart and Munich, Germany, the tunnelling industry will generally be declining in the medium to long-term in Central and Eastern Europe due to the fact that most of the tunnels needed here have already been built."

He explains that Strabag for example is one of the companies keen on offering its tunnelling expertise to other continents, where there is a far greater demand for tunnelling services. Schömig points to North America with projects such as the South East Collector Sewer in the Greater Toronto Area, Canada and the Niagara Tunnel.

Despite this, for the moment some 50 per cent of Strabag's tunnelling activity is carried out in Central Europe. The tunnelling division, which employs approximately 1,000 people, has not noticed any skilled labour shortage. And right now Schömig is focused on tendering for the Visnove Tunnel in Slovakia. The country's Highway D1, of which the tunnel forms a key part, runs from Lietavska Lucka to Dubna Skala. In Germany, Stuttgart 21 and the HSR link between Stuttgart and Munich are highlights, while in Austria the Koralm Tunnel (the ongoing KAT Two and the to-come KAT Three contracts), Vienna's U1 Metro Line expansion, and Preparatory work for the Brenner Base Tunnel are spurring the industry.

There is however significant protection for established companies in the market, says Schömig. "The general conditions of public tenders allow all interested contractors to participate in the Central European tunnelling market. The significant price pressure on the European market combined with local peculiarities, however, has led to the fact that non-European competitors have more or less not been able or willing to join the market over the past years"

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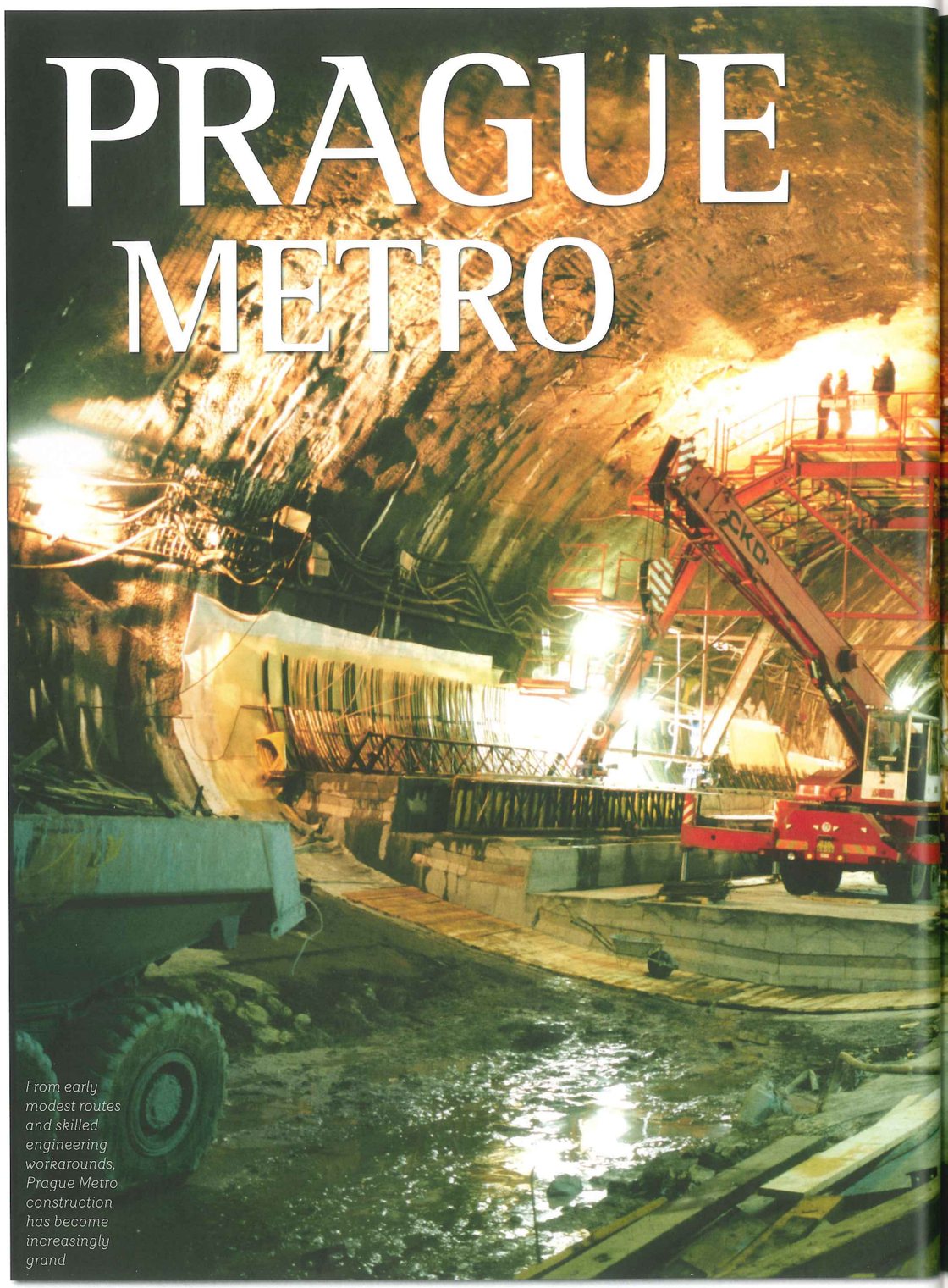
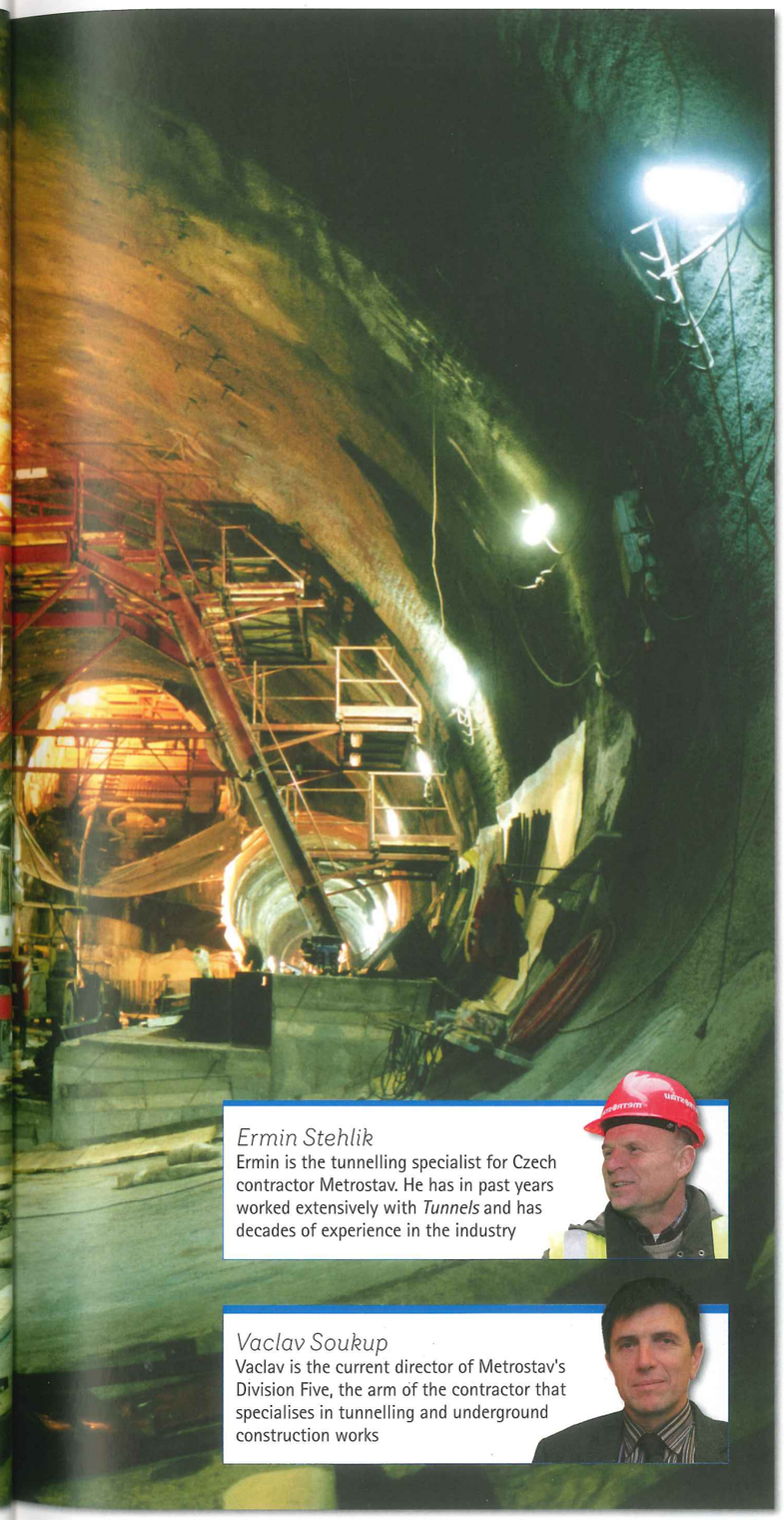
PRAGUE METRO



From early modest routes and skilled engineering workarounds, Prague Metro construction has become increasingly grand



Ermin Stehlik and **Vaclav Soukup** of Metrostav are presenting the keynote talk, 'Prague Metro construction – past, present and future' at UC Prague 2013. This comprehensive three-part article covers Prague Metro construction from its beginnings in 1966 up to the present and into future plans. Early construction covered in this, the first part, was affected by the political situation, with the start of construction based on imported Soviet technologies

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 current director of Metrostav's Division Five, the arm of the contractor that specialises in tunnelling and underground construction works

PRAGUE METRO construction began in 1966 with the building of an underground tramway system for a stretch of the C Line, close to the Main Railway Station. Only later in 1967 was the decision made to change construction to that of a classical deep metro. As of the end of 2012, there are some 59km of metro line in operation in the city, with 57 stations, some 24 of which are mined.

The first metro line: C, was constructed before the changeover to deep metro construction. It was built with shallow tunnels and stations, and as a result all the stations were open cut constructions. Mined stations have been built on subsequent Metro lines, where the tunnels and stations are situated in the Prague bedrock.

Running tunnels passing under the Vltava River are also situated in the bedrock. Thus the choice of technologies and equipment was influenced by the tunnel locations.

From the start of Metro construction, the dominating firms, as their names indicate, were Metroprojekt as the general consultant and Metrostav as the general contractor. The political changes in 1989 brought tendering processes, but nevertheless these two organisations are still important partners of the City of Prague for design and construction of the Prague Metro. On the client's side the firm Investor Dopravnich Staveb (later renamed to Inženýring Dopravních Staveb) has also been present from the beginning.

PRAGUE GEOLOGICAL CONDITIONS

The alignment of the metro lines, especially their depth, was affected by the landscape topography, the need to pass under the River Vltava, and the geological conditions.

The difference in the depth between, for example, Staromestské Námestí Station, and Petriny Station on Line A is around 200m. This shows the significant impact of the landscape configuration. The bedrock consists mainly of palaeozoic age rocks (mostly ordovic), and also to a lesser extent the rocks of Mesozoic era, as chalk period sediments were encountered during construction of Petriny Station on extension of Metro Line V.A. The bedrock outcrops are rather rare; bedrock is covered by weathered materials and alluvial and fluvial sediments.

RUNNING TUNNELS

The time from the start of construction up to 1989 was affected by the political situation, with the methods and experience from metro construction in Soviet cities being applied on the Prague Metro.

Above: *Figure 1, Prague Metro map. Lines are given a letter, each subsequent extension is given a Roman numeral*

200
Meters between the depth of two stations on Line A

The first running tunnel of Line C was bored by a non-mechanised open shield on the Pankrác, Štetkova Street site. The boring went mostly outside the built-up area, but it was necessary to go under the early baroque church of Saint Pancras (including the rotunda dating from the 12th century), which was achieved without any damage to this significant historical monument.

Geological conditions were sometimes complex, with some incidents of, for example, running sand lenses, which called for full lagging of the tunnel face.

In other sections of Line C the shield method was used in combination with segmental lining of 5.1m/5.5m diameter and ring width of 1m. But the standard method was the so-called 'ring method', with Soviet-made erectors used for assembling the lining.

On sections of the tunnel excavated by subcontractor Výstavba Kladenských Dolu (VKD), they used a special erector that created a finished lining diameter of 5.2m/5.6m and ring width of 0.75m.

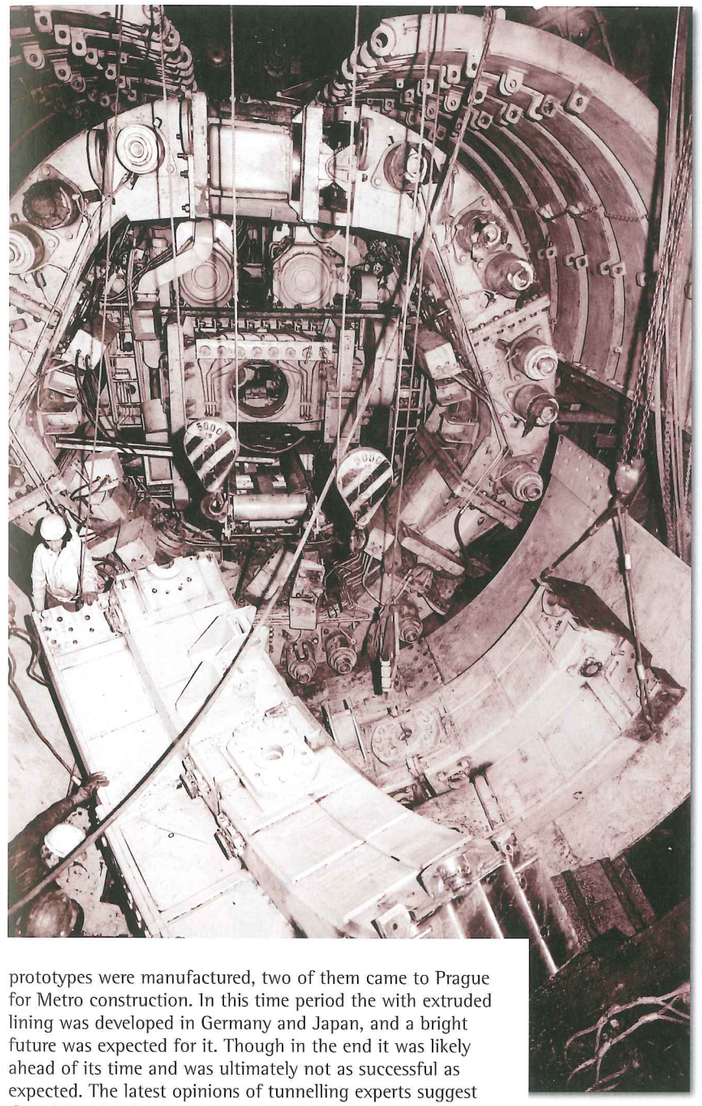
For the ring method, the erector's platforms were used for hand drilling the tunnel face and afterwards for blasting and mucking, mostly by PPN loader (a pneumatic overhead loader with shovel capacity of 0.4m3). The erector then moves to the face, and with the help of a turning arm erects the next ring [6]. Later, Metrostav developed special assembly platforms, used for shorter tunnel stretches.

The next line to be built was Line A, which, as a deep line, was located in the bedrock. Nevertheless, non-mechanised shields were still used in combination with blasting, but the main method remained the ring method with blasting and an erector for lining assembly.

Ahead of its time

Before the first Vltava River crossing, which was on Line A between Klárov and Old Town, there were significant doubts how the bedrock tunnel overburden under the river would react to the blasting. In the end it was decided to apply mechanical boring without blasting work, and for this two mechanised shields, of the type designated 'TŠB-3' were supplied from the Soviet Union [1], [2].

An interesting feature of these machines was the application of an extruded lining. In total three such



prototypes were manufactured, two of them came to Prague for Metro construction. In this time period the with extruded lining was developed in Germany and Japan, and a bright future was expected for it. Though in the end it was likely ahead of its time and was ultimately not as successful as expected. The latest opinions of tunnelling experts suggest that this technology, owing to huge developments in materials, admixtures and equipment, might in the future have considerable usage.

For example, compared to segments there might be fewer problems arising from joints, settlement, and safety. In the future, the existing extruded lining under the Vltava River will be a good reference point. The extruded lining is, in respect of its watertightness, still in a good condition.

Before the first TBM bore, due to the existing uncertainty of boring under the Vltava River, the advance gallery was built, serving for geological surveys, with its concrete invert also providing support to the TBM. The tunnel overburden was improved by grout injected above by boat. The TBM completed both tunnels on the line 1.A going under the river from Klárov to Staromestská, one tunnel from Staromestská to Mustek and, on the line 1.B, the northern tunnel from Mustek station to Florenc station. The maximum monthly progress was 132m (on the 1.B line). Compared to advance rates on the extension of line V.A this is a rather slow advance, but the stretches between the stations were shorter and therefore the learning curve had bigger impact on the rates. The main problem was a need to wait for the extruded concrete to achieve the required strength before formwork could be re-erected. But the main reason for the increase in efficiency is from the huge advancements in TBM technology made in last 20 years.

Above: *Soviet TBM technology was in use in the early years of the Prague Metro*

References: All references will be included with the third part of this series

Since 1985 Metrostav used a shield with a roadheader boom for boring running tunnels. The first prototype was named RŠF-1, and it was the first Czechoslovakian shield equipped with a roadheader boom, the AM-100 produced by Austrian company Voest-Alpine [4]. Coordinated by Metrostav, more than 30 firms participated in developing the machine. On the Metro line II.B this equipment saw an average of 80m per month, the best monthly advance was 164m, which has been the highest rate on running tunnels achieved at that time. During the boring there were problems with keeping correct vertical alignment. There were plans to develop and produce more machines, but after 1989 the development followed a different path.

For running tunnels, during the first period, a cast iron lining was used, which was expensive and and not enough material was available. Therefore a combined lining was often used with the invert segment made of concrete, and the rest cast iron, and later a concrete segmental lining (from Hungary), which was gradually modified by having a one-sided or two-sided flat invert segment. The grouting behind the lining was completed in two stages. After assembling the ring the front space behind the lining was provided with brick wall and upwards filling with low pressure (up to 3 bars) cement mortar grouting. With some distance behind the face the so-called sealing grouting with cement grout and higher pressures up to 10 bars was then applied.

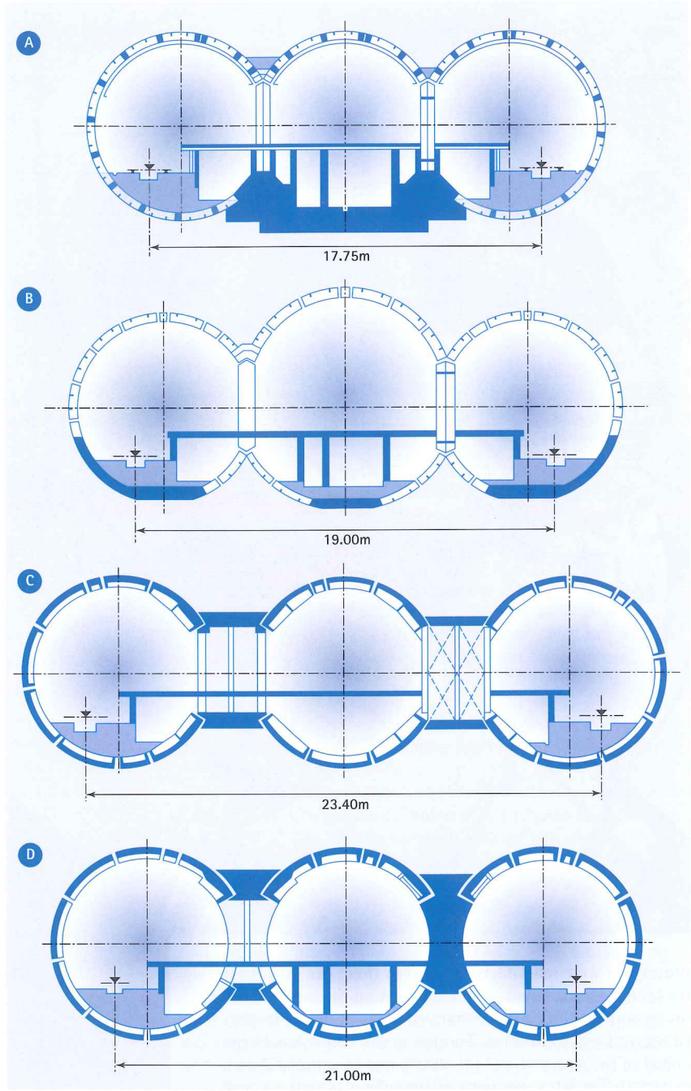
The advantage of cast iron lining was, although with time consuming effort, the possibility to seal the joints with caulked lead. The concrete segment joints were sealed with expanding cement, later using chorda with expanding cement; this seal having its own weaknesses. Generally it could be stated that the sealing of the segmental linings was not optimal and Metrostav in the late '80s started negotiation with Wayss & Freytag for the production of concrete segments with sealing rubber gaskets. The agreement was however not completed due to the events of 1989.

STATIONS AND ESCALATOR TUNNELS

The first mined stations on the Line I.A were so called 'pillar' type, as used at Muzeum Station, or 'column' type, at Mustek Station. Both stations had cast iron segmental lining. Hradcanská and Námestí Míru stations had a concrete segmental lining, and since their construction there has been further development of mined stations with concrete precast lining. That particular lining was similar to the lining used in Kiev (at that time the USSR). Cross passages were created with the help of a in-situ cast reinforced concrete beam, which rested on pillars. These were built after the tunnels were excavated, starting with extraction of relevant segments, followed by reinforcement installation and in the end concreting the pillar width of 1.5m (width of two rings of segmental lining 7.8m/8.8m). This method, undertaken in the complicated and confined underground conditions, and requiring a very high strength of concrete to be achieved (mainly for the beam), called for a change. And such fundamental change happened during construction of station Jirího z Podebrad on Line II.A. The width of the pillar was reduced to the width of the ring, 0.75m. And a steel pillar consisting of two parts, the size of each being similar to the lining segment, was designed.

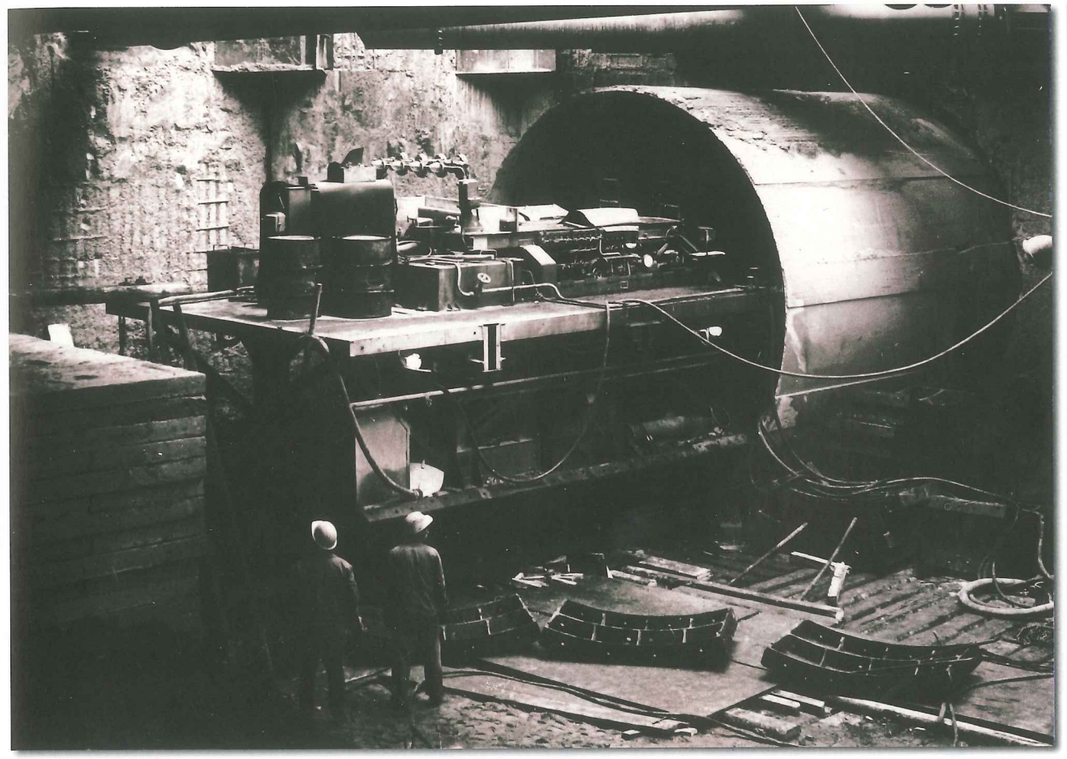
This enabled the installation of pillars by erectors during tunnel excavation. To be able to reduce the pillar cross dimension, the distance between the tracks was reduced from 23.4m to 21.0m. Another change was made by replacing the in-situ cast concrete by steel beam, installed after completing the tunnel, axially on the pillar; the width of cross passage was 3m, the same as in the original type. The steel beam was activated by steel fibre concrete, pressed between the steel beam upper flange and supporting rib of segmental lining.

The construction method used at station Jirího z Podebrad was successful and this type of station was further developed and improved. In the next phases the pillars with steel as a main bearing element were developed, compared to station Jirího z Podebrad, where the bearing element was also concrete. Further, the width of cross passage was increased to 3.75m, the size of the lower steel beam was decreased with the aim to save the steel volume. This station type was in the end standardised and named the 'Prague Type', [3]. On all lines, a total of 12 such stations with precast concrete linings



Above: Figure 2, Development of mined metro stations; A – column type station, Line A; B – column type station, Line B; C – pillar type station, Line A (Náměstí Míru); D – pillar type station, Line B, (Zlámal, J.)

Right: Early work on the Prague Metro project



were built, where the principle of pillar assembly during tunnel excavation, followed by installation of steel beams, was applied.

All escalator tunnels have been built using cast iron segmental linings, most of them with a 7m internal diameter and using erectors during construction. When the layers of sediments with underground water had to be tunnelled through, the cement grouting with 'tube a manchete' method was performed by the specialised contractor Vodní Stavby.

REVIEW OF THE PERIOD UP TO 1989

All things considered, the construction of tunnels and stations in difficult geological conditions, in densely built-up areas of historical city, and with a minimum impact on the surface, was successful. During the construction process a number of in-house methods and design solutions were developed and the result was a civil engineering project, which was presented as a case study of the construction industry. In hindsight it could be stated that the arrangement of automatically awarding the projects to the general consultant and general contractor for the metro construction had a great advantage for the continuity of works for both subjects. There was no need to conduct tender processes and lot of the effort could be devoted to the new solutions and technologies. Of course such efforts were often a substitute, due to the limited capability to import modern technologies and equipment.

The mined metro tunnel construction throughout this time period was oriented to the application of segmental linings. The application of, for example, shotcrete, was not easy to introduce, although there was constant effort to do it.

From today's perspective the waterproofing both of running and station tunnels was a weak point. With the cast iron lining, the joint insullation with caulked lead was very time consuming, but the resulting watertightness was good. Nevertheless, for the stations, protective sheeting collecting the seepage water had to be installed. As for the watertightness, the use and quality of two-stage grouting applied behind the segmental lining, was closely related.

One significant problem was being unable to use bigger equipment for transport, loading and drilling. Constrained spaces in erectors, in combination with rail bound transport, necessitated the use of small loaders, although later continual loaders were introduced to replace small PPN loaders. Another weak point was drilling; basically all the drilling at tunnel faces was done by hand with negative impacts on production and also the health of tunnelling staff. Another weak point has been in lagging of drifts and other temporary excavations, which has been done mostly by concrete or steel sheeting boards with backfill. Only towards the end of this time period, was shotcrete used. The absence of active support by bolts and shotcrete caused occasional overbreaks, sometimes even sinkholes on the surface. But media influence was not as it is today, and such events were not so publicised

Above: The first bored tunnel on Metro Line C, with an open shield

DRYING BACCHUS

Wine caverns need to be protected from vineyard operations above, and other local factors. **Sarah Rippin**, technical writer for Krypton International looks at the products and techniques used to protect the Bacchic treasure trove

AT CLOS de la Tech Winery in California, the goal is clear: to make the New World's Best Pinot Noir. Located high in the Santa Cruz Mountains, Clos de la Tech was founded in 1994 by T.J. Rodgers and Valeta Massey. Using innovative techniques, and working with nature's forces, Clos De La Tech wines claim to be a strong contender in challenging the Burgundies which have traditionally dominated the world of fine Pinot Noir wines.

Their approach of meticulous stewardship of ancient tradition has led them to the challenge of treating a large-scale vineyard with the intimate wine-making style practiced a smaller operation. Clos de la Tech thus began to operate three separate California vineyards to produce their highly limited Pinot Noirs.

A DEMANDING GRAPE

The most challenging of these vineyards is Domaine Lois Louise. This 80-acre (0.32km^2), close-planted, steep-slope vineyard resides at 1,700ft (520m) above sea-level. As this steep incline directly faces the Pacific Ocean, the weather is gruelling, which causes the lowest yield of all three of the Clos de la Tech vineyards.

Though a difficult wine-makers feat, the challenges are worth the effort – the soil, called Sweeney Stony Clay Loam, is deep, loamy clay atop a subsoil of very fractured rock, creating superb drainage with a soil pH of 6.5. These ideal soil conditions, combined with the Californian summers of cool nights and warm days, with a powerful marine influence, is a Pinot Noir paradise.

To make the most of this invaluable land, and retain the intimate wine-making style practiced at the other two Clos de la Tech vineyards, three wine caves were constructed to make the wine at Domaine Lois Louise.

SITUATION

As the vineyards and irrigation were located 10m above the caves, the waterproofing of the caves was essential. If the irrigation flooded the cave where the delicate Pinot Noirs were being made, a large part of the season's crop could be lost.

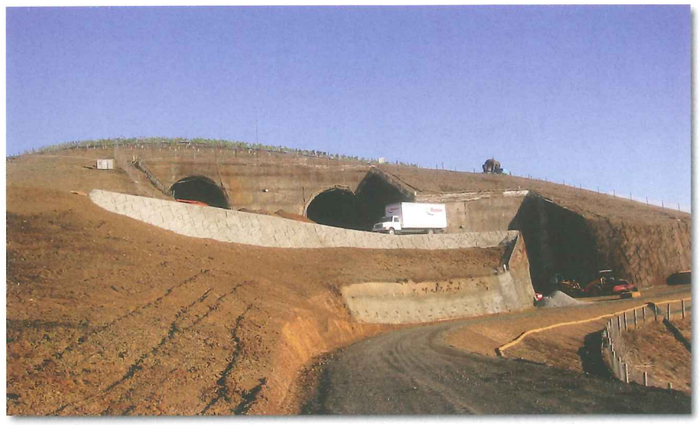
Each of these caves were constructed 30ft (9.1m) high, 30ft wide, and 300ft (91m) deep. The top cave contains a total of 56 fermenters, each one capable of making eight barrels of wine, which translates to ten unique bottle bins per fermenter in the bottling cave. The entire process takes approximately four years from grape to bottle.

The caves, like any tunnel structure, can be subjected to temperature changes, corrosion damage and freeze-thaw cycles which affect the structure's durability. Proper waterproofing prevents the penetration of moisture and chemicals into the concrete and reinforcing components, ultimately protecting the durability and structural integrity of the concrete; overall, prolonging the life of the cave or tunnel. Kryton's Concrete Waterproofing System was used to waterproof the wine caves, because a traditional membrane system would not work with the shotcrete application.

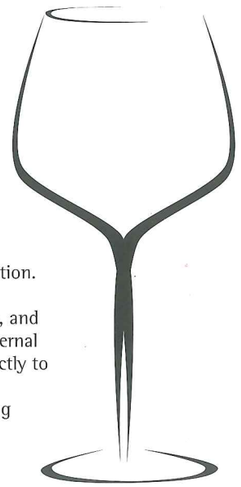
SOLUTION

When using shotcrete, it is likely that there will be much less uniformity of coverage across a traditional waterproofing membrane, than with other concrete installation methods. The structural bond that must occur between the traditional stick-on waterproofing membrane can be reduced because of overspray from the shocrete. For these reasons, the project's architect and contractor, Drill Tech Drilling & Shoring, turned to Hill Brothers Chemical company for a waterproofing solution. Hill Brothers distributes Kryton's crystalline waterproofing products, and recommended Kryton's Krystol Internal Membrane (KIM) to be added directly to the shotcrete itself.

The KIM concrete waterproofing admixture was added directly to the shotcrete mix to create the 450-600mm thick walls that formed the huge wine caves. KIM is an integral crystalline concrete waterproofing admixture; and a PRAH (permeability reducing admixture – hydrostatic conditions as referenced in ACI 212.3R-10). When combined with water, KIM's proprietary chemicals react to form millions of needle-like crystals. These crystals grow and fill the capillary pores and micro-cracks in the concrete, blocking the flow of water. As time passes and stresses form new cracks, any incoming moisture causes the crystals to reactivate – ensuring continuous waterproofing for the life of the concrete structure. Permanent and reliable waterproofing was essential at the Clos de la Tech Winery, as the vineyard and irrigation was only 10m above the caves where their carefully crafted Pinot Noir's were being made.



Above: The wine caves are each built for a different wine-making purpose

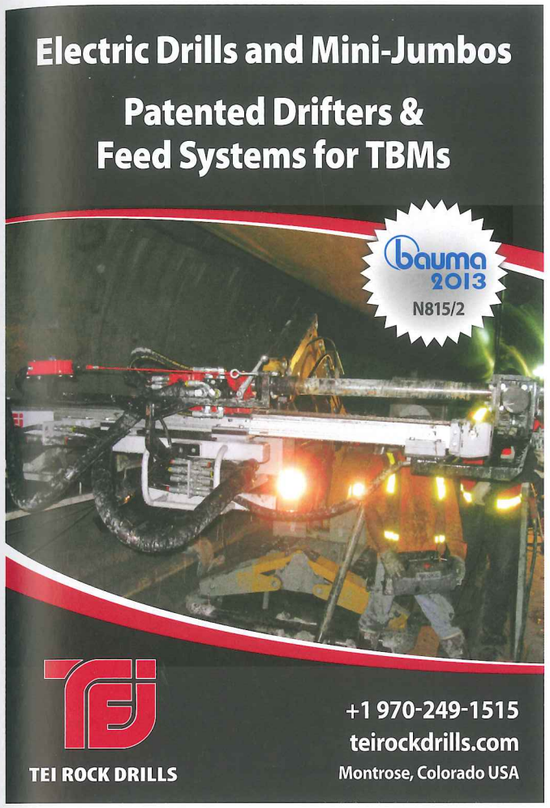


The three caves were carefully dug 1m at a time and immediately reinforced with shotcrete to prevent cave-ins. Unfortunately this approach was not successful and there were two cave-ins in the center cave during construction. The cave-ins vented all the way to the surface and tore two 9m diameter holes in the vineyard. KIM was used as an injection-fill system to fill the two holes caused by the cave-ins.

In all, more than 2,000cu.yd of shotcrete were treated with KIM. The project also used Krystol T1 & T2 Surface-Applied System for the office areas within the tunnels. As a surface-applied treatment for new and existing concrete, Krystol T1 and T2 grow crystals deep into concrete, and outperform direct competitors for waterproofing properties in independent side-by-side tests. The concrete itself becomes the waterproof layer and the surface treatment is not required to remain intact for the system to be effective.

KIM can be added to the concrete at the plant, or on-site to the mixer truck. It turns the concrete itself into the waterproofing membrane – eliminating the need for any traditional external membrane to be applied. KIM and the Krystol Waterproofing System reduce labor, construction schedules and costs for concrete waterproofing. KIM also works to reduce shrinkage and cracking during the curing process. The Krystol concrete waterproofing system also protects the structural rebar from corrosion and provides a durable, leak-free solution for new or existing tunnel construction.

The caves were each built for a different purpose, and work as one system. Built at different heights, the caves used the force of gravity to allow the wine to flow from one cave to another. There, the grapes are foot-crushed and native-yeast fermented, before being siphoned by gravity to brand new Francois Freres barrels in the barrel cave. The wines from the cave manufacturing process at Clos de la Tech's Domaine Lois Louise vineyard are set to be available for sale in 2016



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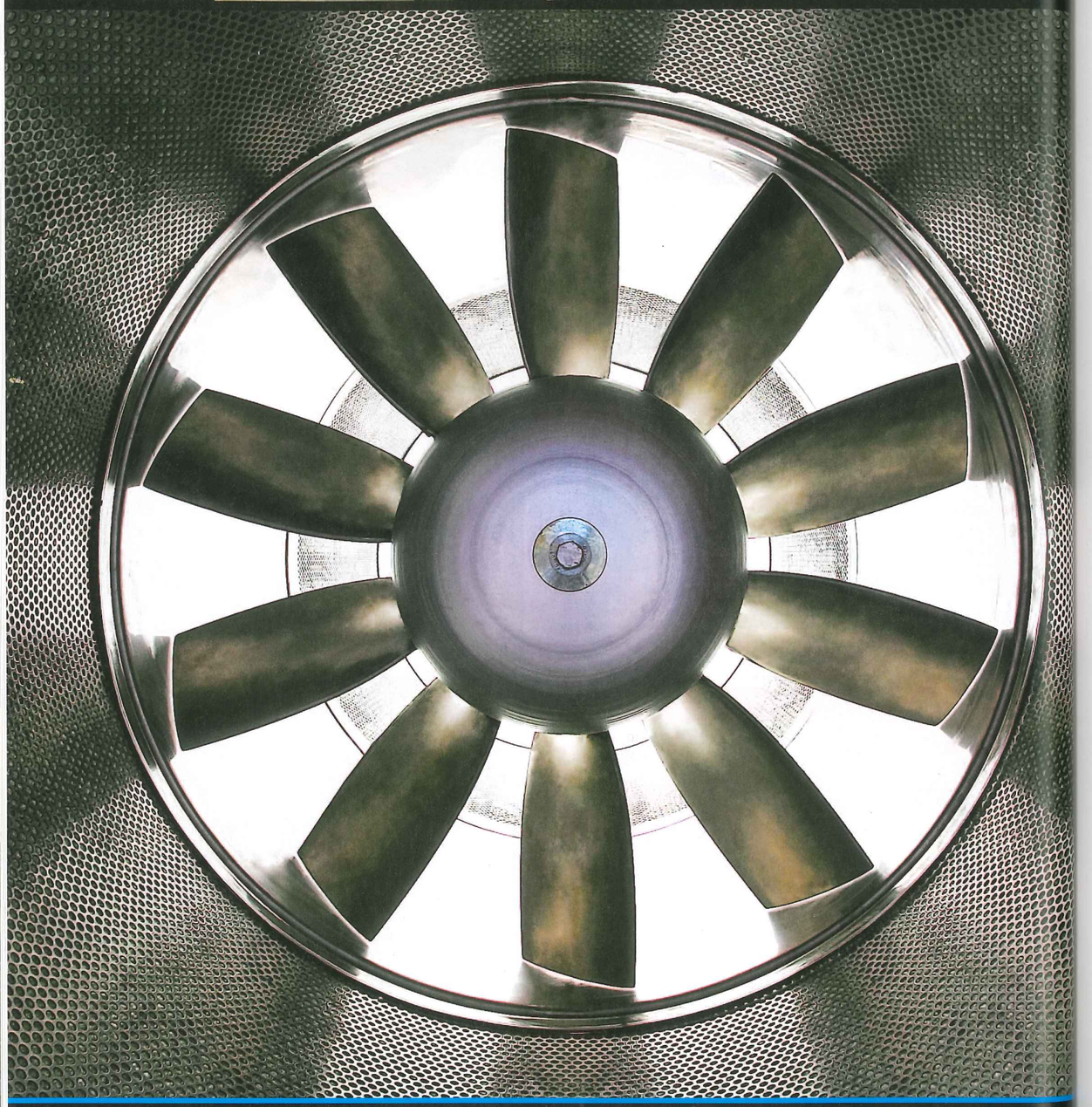

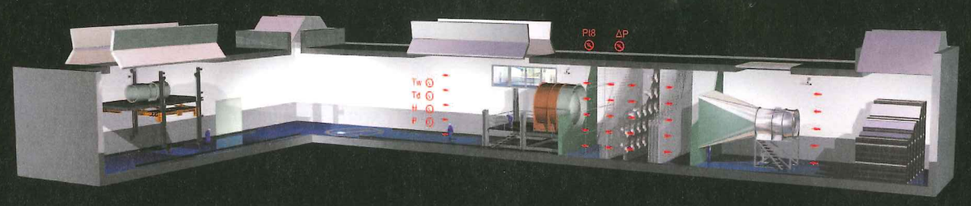

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POLYMER MODIFIED SCL FOR SINGLE SHELL WATERPROOFING CONSTRUCTIONS

Klaus Bonin of Wacker Chemie gives two examples of successful waterproofing in tunnel construction. The first covers water ingress to a mountain mine access tunnel, while the second covers waterproofing for a pressurised water tunnel. Watertightness was achieved by polymer modification

SPRAYED CONCRETE is used as the first cover layer in the construction of some tunnels; it generally is not required to perform any other function. Two examples of successful waterproofing of tunnel constructions are cited below. The first example describes a mine-access tunnel with water ingress from the mountain, while the second outlines the waterproofing of a pressurised water tunnel. In the tunnel sections under consideration, waterproofing was achieved by polymer modification. An inspection after a two-year service life revealed that impermeability was undiminished. The second example describes the renovation of a pressurised water tunnel, where water loss from the tunnel into the mountain was reduced. After two years of operation, an inspection showed that the sprayed-concrete shell was still intact.

REQUIREMENTS FOR SPRAYED CONCRETE LININGS

Concrete shrinks, and this basic property must be taken into account when constructing sprayed-concrete shells. Free shrinkage is influenced by various factors, such as the water/cement ratio, the solids content, the atmospheric humidity and the aggregate type. The conventional concept of shrinkage does not factor in the adhesion to the substrate i.e., adhesive bonding between the rock and the concrete shell. When considering bonding, one invariably thinks of bonding materials or composites. However, concrete is in itself already a composite, comprising additional components which include an aggregate, cement and reinforcing steel, (a mixture of different components constitutes a bond). The European standard EN 1504-3 regulates concrete renovation and describes and examines multi-layered composite materials. In contrast to a concrete member that is subject to free shrinkage, the shrinkage described in the standard is restricted by the adhesive bond. Since deterioration of the adhesive bond is the decisive factor in the application, the shrinkage test in the standard was replaced with a tensile adhesion test. Reprofiling material applied to old concrete not only has to comply with a classified compressive strength; its tensile adhesive strength must also be adequate. This material bonding also applies to sprayed-concrete applications: the rock and sprayed-concrete layers and spray membranes (if used) or shell concrete also constitute a bond within the single-shell tunnel construction. Although economic considerations have raised awareness of the value of single-shell tunnel construction, conventional construction methods are generally used. Yet, while the deformation of the mountain subsides with time, and the sprayed concrete layer is disregarded in terms of structural analysis, the inner shell can be calculated accurately, because it is unaffected. The rough sprayed surface of the initial layer suffices to allow for good adhesive bonding between the sprayed concrete layers; the concrete structure can therefore be regarded as monolithic.

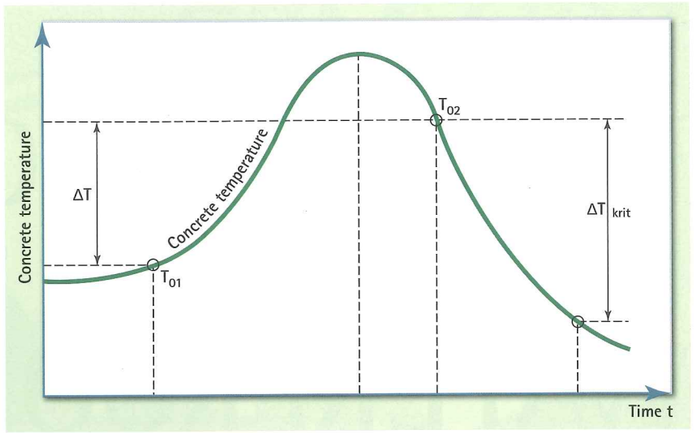
Conventional construction methods using sprayed concrete as the initial cover layer, and a film sealant followed by a concrete shell or precast segment, are based on the assumption that the safest waterproofing possible is thereby provided.

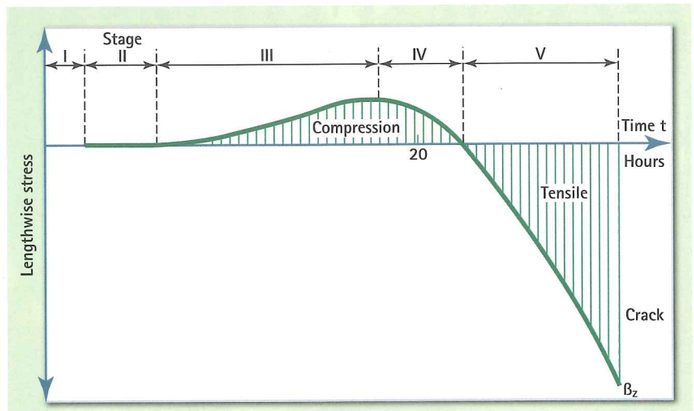
WATER IMPERMEABILITY OF TUNNEL CONSTRUCTIONS

Tunnel constructions must be leak-proof commensurate with their use. Here the term 'leak-proof' or 'impermeability' must be examined more closely. Leakage rates are a standard category in building requirements stipulated by STUVA (DE). The unit used for water leakage is liter per square meter and day (lt/m² per day) per 100m tunnel length. The SIA 272

(CH) (Swiss Society of Civil Engineers and Architects) classification for impermeability ranges from 'small moist areas' to 'flowing water' [6]. The common concern was to define classes and create categories which enable the contractor to propose or implement an appropriate waterproofing process, and for the customer to specify and monitor the impermeability required for his building projects. The fundamental question to be asked in the development of a construction system is whether to assess a sample or a building component. The advantage of samples is that sampling is performed under highly controlled, reproducible conditions; consequently, after successful testing, the sprayed concrete sample can be classified as leakproof.

It is far more difficult to test building components, since they are influenced by many boun- dary conditions. Built-in sprayed concrete, in particular, is not only subject to purely material fluctuations; here factors such machinery, spraying procedure, climate conditions and even the nozzleman must be taken into account, as they all determine the quality of the sprayed-concrete shells. The quality of the application can also be improved by training the machine operator to qualify for nozzleman certification, since the human factor and materials both influence quality equally.





Above, top: Figure 1, Temperature curves in fresh concrete

Above, bottom: Figure 2, Stress curves in fresh concrete with restricted deformation

THREE TENSILE ADHESION STRENGTH AND CRACKING IN COMPOSITE MATERIALS

Tensile adhesion strength is one parameter used to describe material bonding. A comparison between typical values according to EFNARC (European Federation for Specialist Construc- tion Chemicals and Concrete Systems) and EN 1504-3 is listed in Table 1. EN 1504-3 is of particular interest because shrinkage is not viewed as a single property. Instead, bonding, adhesion and toothing of interfacial layers are taken into account.

When sprayed concrete is applied, factors relating to stresses, such as the temperature of the concrete and the ambient temperature must be taken into account. When cement hydrates, the temperature rises, see figures. 1 and 2, above. However, the progressive strength development and subsequent cooling result in tensile stress. The combination of sprayed concrete and an accelerator causes the temperature of the fresh concrete to rise.

The nozzleman can exploit the hydration heat as it indicates whether the concrete formulation has started reacting, i.e., he observes or measures the temperature of the sprayed concrete

Table 1. Requirement comparison of tensile adhesion strength of sprayed concrete

Type of Adhesion	Minimal Tensile Adhesion Strength on Concrete [MPa]	Minimal Tensile Adhesion Strength on Rock [MPa]
EFNARC Tab. 9.5.1		
Not load bearing	0.5	0.1
Load bearing	1.0	0.5
EN 1504-3 Tab. 3 (Measurement of restricted shrinkage and adhesive bond using tensile adhesion strength)		
Not relevant for structural analysis	0.8	-
Relevant for structural analysis	2.0 - 1.5	-

Source: Klaus Bonin

Table 2. Formulation and test results of concrete test specimen according to DIN 1048-5

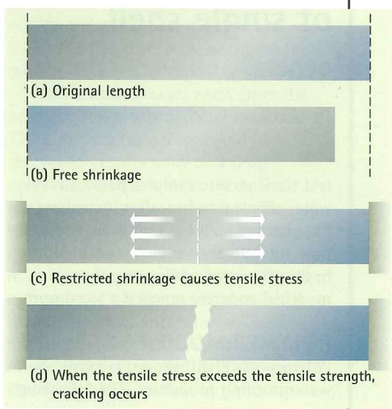
Mixture		Reference		Polymer	
Milke CEM 42,5N	kg	400		400	
River sand 0 - 4 mm	kg	1720		1720	
Polymer Binder	% on CEM			16,4	
Defomer	% on CEM	0,26		0,26	
PCE	% on CEM	0,6		0	
w/c ratio	0,50	0,50		0,50	
Fresh mortar density	kg/m³	2310		2330	
Air pore content	%	7,0		5,0	
Crack formation		*cracks visible*		*no cracks visible*	
Test condition water pressure and time		*Water uptake (ml)*	*trend*	*Water uptake (ml)*	*trend*
3d 1,5 bar		0; 0; 15		10; 0; 0	
7d 1,5 bar		0; 0; 30		25; 0; 0	
7d 1,5 bar + 1d 5 bar		15; 20; 80		50; 20; 20	
7d 1,5 bar + 3d 5 bar		25; 25; 80		75; 25; 25	
7d 1,5 bar + 7d 5 bar		30; 40; 150		75; 25; 25	

Source: Klaus Bonin

"Concrete shrinks and this basic property must be taken into account when constructing sprayed concrete shells"

surface. The concrete development serves to harmonise the strength development, tensile stress, tensile adhesion strength and shrinkage, such that cracking does not occur. The strength curves J1 to J3 specified in the directive for sprayed concrete are frequently implemented. However, formulations with a high early strength range of J3 should only be used in special cases, as they also cause higher thermal stresses.

In addition to the thermal stresses occurring in the fresh concrete, the physical shrinkage of the hardened cement must be taken into account during aging: the sum of the forces causes cracking if cohesion within the concrete is exceeded. Shrinkage alters the length, and the force exerted inside the concrete is changed into tensile stress. An example of the force behavior in dry shrinkage is illustrated in Figure 3.

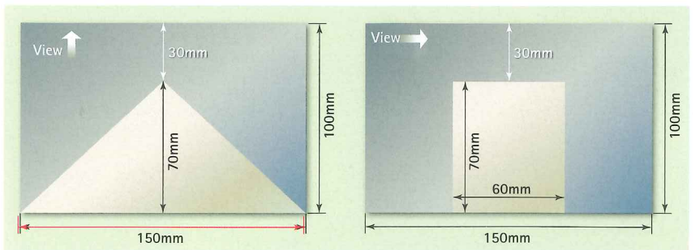


Above, right: Figure 3, Free and restricted shrinkage as from ACI 224

DEVELOPMENT OF A TEST SPECIMEN

The shrinkage at a tunnel surface is much more complex; material roughness and applied thickness are only some of the impacts. To get more information about the shrinkage behavior we de- veloped a test specimen to combine some of the aspects. The inlay specimen is made out of a solid but porous concrete, it's comparable to a drainage concrete. The size is a triangle of 150mm by 60mm, height in the middle is 700mm. This concrete fragment is placed in the middle of a 150mm by 150mm by 100mm mold and is filled up with concrete.

The shrinkage and shear force is quite complex, we have different heights and angels see Figure 4. Storage condition: The surface was covered for three days with a plastic sheet and stored at 23°C, followed by 25 days 23°C / 50 per cent



Below: Figure 4, Schematic of the test specimen

Table 3. Impermeability according to DIN 1048-2

Mixture	Without polymer	With polymer	With polymer	With polymer
Type of Polymer	-	Liquid	Liquid	Solid / Powder
Dosage (%)	-	5 (2.5 solid)	10 (5 solid)	5 (solid)
Accelerator (%)	5	5	5	5
Penetration (mm)	26	25	49	34

Source: Klaus Bonin

relative humidity level.

After the drying time, the surface of the specimen and marked the cracks were scanned. The observation was that some hair cracks in the center of the specimen were found, following the direction of the stress directions. For the proofing of water tightness a test according to DIN 1048-5 was performed. At the beginning of the water pressure

"Although economic considerations have raised awareness of the **value of single shell,** generally conventional is used"

test the concrete samples had a similar water absorption but after increasing the pressure to 5 bar and longer test time the reference sample continued to absorb water, while the polymer modified concrete reached a maximum.

POLYMER-MODIFIED SCL

Polymer-modified sprayed concrete has waterproofing properties. The following application examples and tests show that this process reduces the tendency to crack, thereby increasing watertightness.

The copolymer used in the investigation was based on Vinylacetate Ethylene, having a high flexibility with a glass transition temperature below 0°C.

Tests performed on coredrill samples taken from sprayed concrete slabs showed that sprayed concrete is also watertight. The results of concrete core drill samples were stored for three days at a water pressure of 5 bars, in accordance with DIN 1048, are listed in Table 3.

A higher penetration depth was noted for polymerisation exceeding five per cent; however, a reduction of the building component's susceptibility to cracking is ample compensation for this.

The erection of a crack-free and therefore impermeable structure is the actual challenge facing waterproof sprayed concrete, and building component or individual tests only reflect some of the requirements.

All types of cracks can be avoided more effectively with waterproof single-shell or, alternatively, monolithic construction methods. The use of polymer binders reduces shrinkage by improving bonding and cohesive forces in the actual concrete mixture.

A crack appeared in the reference concrete applied to a 0.5m by 0.5m raw limestone slab, which was manufactured without polymer. The crack was 0.6mm wide. The reference samples with polymer had no cracks, or cracks of 0.2mm maximum width.

The traditional concern regarding shrinkage in sprayed concrete is to increase adhesion or bonding. When adhesive bonding is good, shrinkage forces, which lead to tensile stress in restricted shrinkage, are reduced by the adhesive force.

The sum of all the forces remains intact. This principle is also the basis of the shrinkage test as is specified in the standard EN 1504-3, according to which structural bonding only exists when the levels of adhesion between the interfacial layers are high.

Table 4. Tensile adhesion strength in a sprayed-concrete bonding test

Mixture		Reference	Polymer
W/C		0.46	0.46
Grain Size	mm	0/8	0/8
CEM II 42.5 A-LL	kg/m³	400	400
Accelerator	%	7	7
Polymer binder (liquid)	%	-	7.5
Superplasticizer	%	0.8	0.5
Flowabilty (immediate)	cm	58	57.5
Fresh mortar density	kg/m³	2,183	2,160
Early strength	Penetration	J2	J2
Tensile adhesive strength 28d (sprayed on concrete slab)	N/mm²	0.45	1.25

Source: Klaus Bonin

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The improvement of the tensile adhesion strength measured on sprayed-concrete samples on a concrete slab is shown in Table 4. Higher levels of adhesion can promote resistance to cracking effects. Polymer binders are used in Polymer Cement Concrete (PCCs).

The reduction of the elastic modulus and the increase in the forces causing cracking are described in the test.

APPLICATION IN MINING ACCESS ROAD, THE CLARA TUNNEL

The successful waterproofing of the mining access, the Clara tunnel in a salt mine in Stetten (Germany) using polymer-modified sprayed concrete was presented at World Tunneling Congress 2010. The sprayed-concrete formulation comprised 7.5 per cent liquid polymer (3.8 per cent solid).

After a two-year service life, an inspection was conducted to determine impermeability.

The area in question measuring 400 to 500m was inspected, and the documentation thus showed that impermeability had not deteriorated.

In 2008, the unmodified concrete, here at 430m, showed typical lime efflorescence caused by water penetration, small hair cracks and also large flaws.

These typical lime deposits which have formed on the surface are a good indicator. Through the use of the SIA 272 classification, they indicate class two for polymer-modified concrete (considered almost watertight – classed as watertight) and class four for standard concrete (considered highly susceptible to leaks).

■ *Klaus Bonin first presented on the topic of this paper at WTC 2012 in Bangkok*

THE PRESSURISED WATER TUNNEL IN HINTERMUHR, AUSTRIA

Pressurised water tunnels, like those used in pumped-storage hydropower plants, have become common building constructions. Their purpose is to minimise influences on the water equilibrium of the mountain concerned: they should not loose water, nor draw from the ground water.

The pressurised water tunnel in Hintermuhr, Austria, erected between 1988 and 1992, was largely left in its natural state due to good geological conditions; problem areas were treated retrospectively.

Since the tunnel is completely filled with water during operation, and is pressurised by a water column of approximately 15m, renovation became necessary to reduce water loss. Notwithstanding injections performed during previous renovation measures, approximately 50m in total still leaked to such an extent that inner rings consisting of 100mm sprayed concrete were installed in several locations. During renovations in April 2009, polymer-modified dry-mix sprayed concrete was used. The polymers were added to the mixing water in the injection nozzle.

Another advantage, apart from the waterproofing, was reduced rebound. The construction period could be shortened considerably as a result, and far less material was used. The restoration was successful and the tunnel is still watertight and complies with the relevant regulations. An inspection conducted in May 2011, after two years of operation, demonstrated that the sprayed concrete shell had remained intact, and the spray pattern of the concrete applied in 2009 was still clearly visible in 2011.

CONCLUSION

The formation of cracks and, therefore, their prevention, are of crucial importance to waterproof, single shell tunnel construction. Both practical examples demonstrate that polymer-modified sprayed concrete has lasting waterproofing properties when used for pressurised water applications. Polymer binders increase adhesion to the substrate andimprove the adhesive bonding strength.

Due to the influence of flexible polymeric properties in otherwise rigid cementitious concrete structures, stress factors can be averted or counterbalanced, and the sprayed concrete becomes more resistant to cracking

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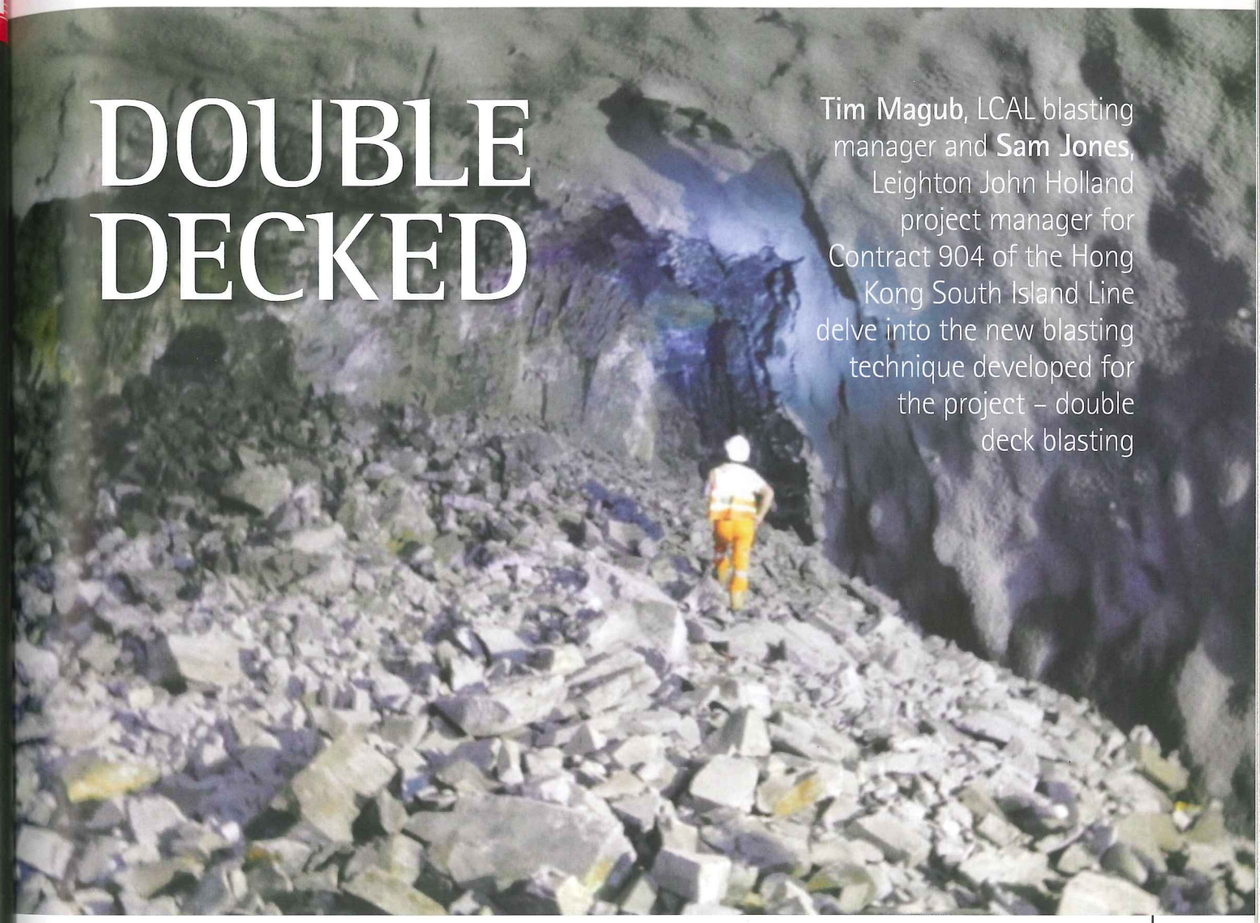
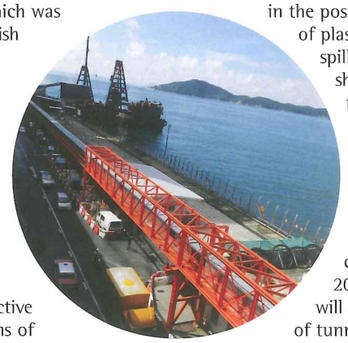


Tim Magub, LCAL blasting manager and **Sam Jones**, Leighton John Holland project manager for Contract 904 of the Hong Kong South Island Line delve into the new blasting technique developed for the project – double deck blasting

JOHN HOLLAND, in partnership with Leighton Asia, is constructing the transport infrastructure project Contract 904, as part of the South Island Line (East) Rail project. The South Island Line (East) will be a medium-capacity railway covering approximately 7km from Admiralty Station to South Horizons Station on the south side of Aberdeen Harbour, with intermediate stations at Ocean Park, Wong Chuk Hang and Lei Tung. When completed, the South Island Line (East) will provide fast and reliable railway service for communities in the south of Hong Kong Island and help ease traffic congestion at critical bottlenecks like Aberdeen Tunnel and the central business district.

The project is located on the island of Ap Lei Chau at the southern side of Hong Kong island and requires extensive constructions works to be completed in close proximity to the existing residential estates of South Horizons and Lei Tung.

The project also has areas of significant cultural heritage, including 18th and 19th Century temples, historical grave sites and the remains of the former Aberdeen Battery, which was destroyed by the British forces prior to the surrender of Hong Kong in 1941.



Owing to the site access constraints and location for the project, detailed planning and methodology innovations have been required to ensure the most effective and responsible means of environmental and heritage management and protection have been implemented to deliver the project works. The project team has developed and pioneered the use of 'Deck loading' in Hong Kong to minimise the impacts of blasting operations and demonstrated a strong sense of environmental duty through the project team's participation in the post typhoon clean-up of plastic pellets which spilled from a container ship and affected the marine environment.

The project was awarded in May 2011, construction commenced in July 2011 and is planned for substantial completion in July 2015. The joint venture will construct 1.1km of tunnels and two new underground stations at Lei Tung (LET) and South Horizons (SOH) as part of the contract, along with related plant and ventilation buildings. Approximately 1km will be primarily

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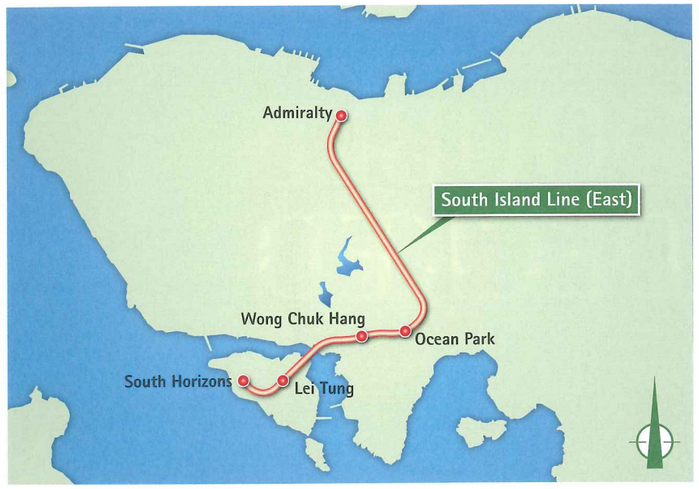
constructed by drill and blast mining techniques, with the remainder using the cut and cover method. The mined tunnel will be predominately a twin track single-bore tunnel. The tunnel splits into two single-track tunnels at the approach to the LET Station and continues as two single-track tunnels from LET to the interface with the cut and cover tunnel at Ap Lei Chau Drive. The drill and blast also includes two pedestrian access adits and a vertical shaft.

The drill and blast tunnels are predominantly beneath the mountain of Ap Lei Chau. The geology along the alignment is in the most part moderately strong to strong grade III and II rock. Indicated compressive strength is of the order of 200MPa and above, with high abrasivity.



Above: Figure 1, Alignment map of the South Island Line (East) in Hong Kong

The alignment also passes in close proximity to high voltage (132kV) cable tunnels, a water reservoir, steep slopes, retaining walls, water distribution pipes, schools and high rise housing developments. As a result, the maximum instantaneous charge (MIC) weight that can be fired while blasting for tunnel excavation has been severely limited. MIC's were reduced down to less than 0.1kg with single deck advance lengths limited to 0.5m. Here double decking could achieve 1m.

The cut and cover tunnel consists of twin, single track, reinforced concrete box structures extending from the interface with the mined tunnel to an integrated ventilation chamber structure. The shaft at South Horizons is built using cut and cover construction methods. Further there are two rock slopes that need to be cut to construct plant and ventilation buildings. The JV needs to erect a temporary traffic deck at the South Horizons Station to maintain the operation of the public transport interchange while work will continue below.

METHOD MANAGEMENT

The John Holland Tunnelling Division partnered with Leighton Asia to develop a new blasting technique for Hong Kong to counteract significant constraints on charge weights (explosive quantity per drilled hole).

The charge weight constraints imposed by the MTR were recognition that most sections of the drill and blast (D&B) tunnels were in close proximity to sensitive receivers and hence could be potentially affected by blasting operations during construction. These imposed constraints resulted in the designed the explosive weights to be low (in some cases theoretically zero), reducing the possible pull length (length of advance per blast) and as result extending the program duration. JHT was able to develop the concept of 'deck loading', effectively doubling the pull length of many originally constrained blasts.

In addition, JHT were able to develop the expertise and promote understanding within the JV for this pioneering technique, in Hong Kong, where traditionally new techniques are difficult to get accepted.

The JV was awarded the contract for the South Island Line (E) 904 Lee Wing Street Ventilation Adit in May 2011. Construction works began in July 2011 and substantial completion is expected in July 2015.

Blasting commenced in March 2012, operating under

Bird's eye view of a compact site chosen for double decking

restricted maximum instantaneous charge weights (MIC's) due to the nearby presence of sensitive receivers. The decision was made to design and execute double decked tunnel blasts to maximise the metres advanced per blast.

FIRST IMPLEMENTATION

In April 2012 the first double-decked blast was fired resulting in an advance of 3.2m, double that could be achieved with the traditional single explosive deck blast. Over the following 12 weeks a further 19 double decked blasts were successfully initiated culminating in July when a 5.8m advance of the 120m² blast face was fired resulting in 696 bank cubic metres being broken.

The successful design and execution of double decked tunnel blasts was made possible by ensuring that the pyrotechnic delay elements of each detonator in the blast were active (burning) before the first blasthole detonated. The initiation sequence was therefore a key element in the blast design process.

Fragmentation of all double decked blasts was considered excellent, enabling mucking-out to be completed in the shortest possible time.

The Lee Wing Ventilation Adit and the running tunnels pass under numerous sensitive receivers which have specific vibration (peak particle velocity) limits expressed in mm/sec. The sensitive receivers control (usually reduce) the MIC's and therefore the advance lengths. The first 20 double decked blasts pulled a total of 77m, double the expected pull utilising a single decked (traditional) blast design using a very low average powder factor of 0.86kg/m³. The double decked tunnel blasting technique will be regularly employed to achieve the longest possible advance, shortening the excavation time required to complete the project drives.

CONCLUDING REMARKS

The technique is applicable to urban hard rock excavation and tunnelling works, there are future potential benefits to be reaped from the use of this technique, such as on deep foundation works, metro station, shaft and tunnel excavations. The deck loading method has been employed quarrying, and shaft/station works in Australia, Hong Kong and Singapore however this was the first use of the method in a tunnelling application in Hong Kong.

This can be used in tunnelling where the MIC restrictions are imposed in competent rock and production is possibly limited

Double decking

During the tender period John Holland's tunnelling business worked closely with Leighton Asia to develop a new tunnel blasting technique that would counteract the project constraints. The JV pioneered the use in tunnels of two explosive charges (known as decks) within a single blast hole drilled to approximately twice the normal depth, a technique now called 'double decking'. The technique uses delays to initiate the two decks at different times to reduce the amount of explosive detonated at a given instant to minimise vibration and double the advance length achieved in a blast cycle.

This is a method for use when MIC's are restricted. It gives you the opportunity to effective get twice the blast length for a given MIC and increases the production rate.

0.86

The average powder factor used in kg/m³. It doubled the pull expected from the traditional methodology

Above: It is hard to get new methods approved in Hong Kong

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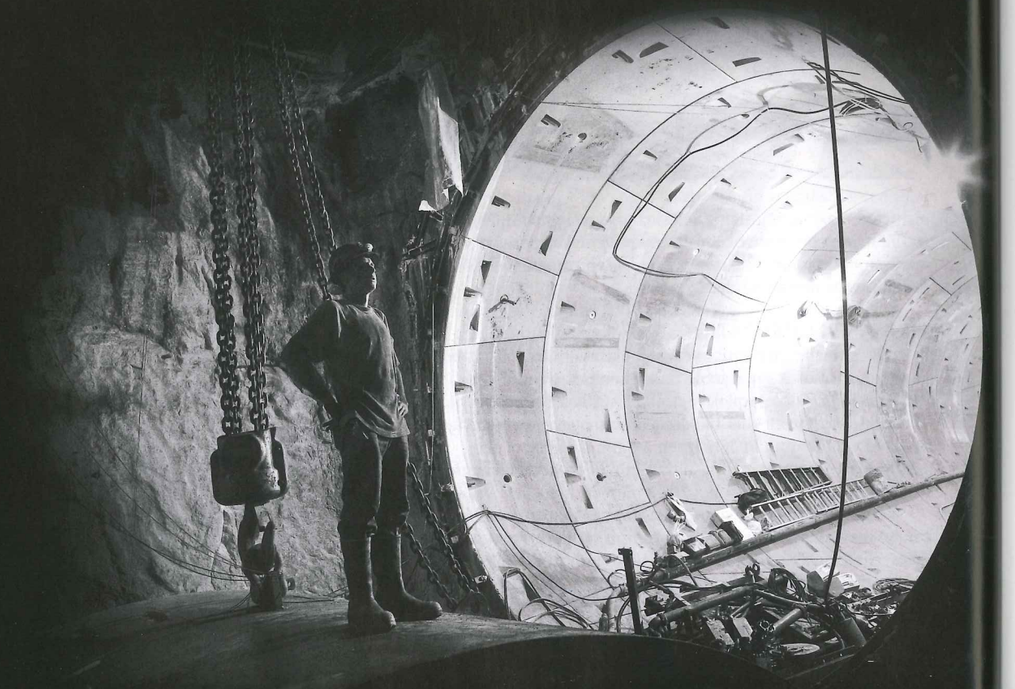

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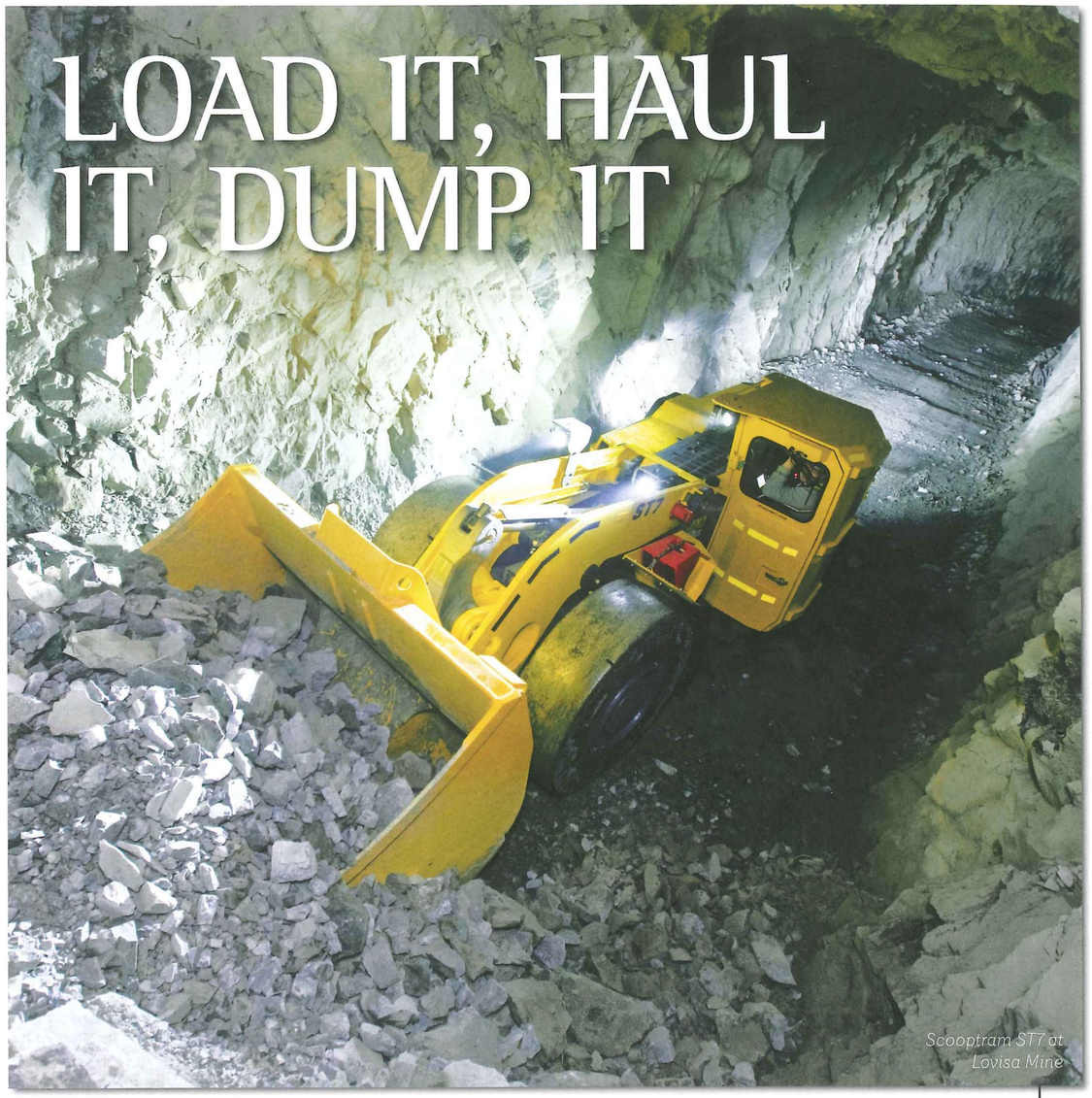

Scooptram ST7 at Lovisa Mine

In this insight take on construction vehicles, technical journalist **Jodie Satterthwaite** looks to the mining industry for underground requirements

IN AN industry renowned for its low return on investment, selecting the most efficient mining machine is crucial to the profitability, and productivity, of the mine. On the surface, this could be considered straightforward. Earth movers above ground have no restrictions on their size and, when it comes to choosing bucket capacity , payload size and the most fuel-efficient design, the sky's the limit.

It's a slightly different story, however, when machines are taken underground. In order to achieve the same productivity as on the surface, underground

Jodie Satterthwaite
Jodie Satterthwaite is a freelance journalist specialising in the construction and architecture/design sectors. Her experience includes work for Middle East Economic Digest

machines must be cleverly designed to incorporate the necessary production functions, as well as the added features essential for the underground environment. Machine size is restricted due to the narrow working spaces and rock conditions. The salty, damp and corrosive environment places added pressure on machines to work efficiently and to capacity and, precious production hours can be lost in the long commute from the entrance to the working face. In short, machines underground have to work harder for their keep than their surface counterparts.

But there are machines built to withstand the harsh conditions underground. A load haul dumper (LHD) is the specialised machine used to scoop material, which is then dumped into haul trucks ready to be taken to the surface. With the capability to scoop between three and 15t in one pass, these are no lightweight machines. Their core function is to get material underground to transport, safely, quickly and efficiently. Descending to depths of up to 2,500m and climbing inclines of up to 11.5 degrees, these vehicles are the Olympians of their field.

Above: Mine Truck MT6020 on site. Environmental concerns have placed increasing restrictions on diesel vehicles

"Without the restrictions that having a human operator in the cab places on underground operations, machines are able to **significantly increase productivity levels**"

ONE SIZE DOESN'T FIT ALL

Mine owners have to weigh up several considerations when in the market for an underground machine. Perhaps the first and foremost is the question of diesel or electric machines. While the demand for diesel still outstrips that of electric models, there has been rising interest in electric loaders and trucks in recent years.

Electric machines tend to be used mainly in mass mining methods such as block and panel caving. The major advantages of electric machines are their running and energy costs which are considerably lower than diesels. Electric machines run at 95 per cent efficiency whereas only 30 per cent of the fuel's energy in a diesel motor is used in loading and tramming operations, with the rest lost as heat.

Electric models are not without their issues however. They are run by power from a cable, attached to power supply, which reels on and off as the vehicle moves. For that reason, they can be less flexible than diesels. Plus, as well as the obvious risks of damage to the cable as it travels through the tunnels' twists and bumps, the reel must also have a large diameter to help preserve the life of the cable. And while an electric machine can be considered to be more cost effective than a diesel, this is only true if the infrastructure to run power to the machine is readily available. To install it at brownfield sites can be a complicated and expensive process.

The increasing cost of oil and gas, as well as the ventilation issues that inevitably come with running a diesel engine underground, has no doubt played a part in the rising popularity of electric machines. Environmental concerns, legislation on emissions, health and safety, air quality and ventilation are placing more restrictions on diesel engines. Mines need a lot of ventilation to keep diesel machines

underground cool as well as removing harmful gasses. Plus, diluting emissions of carbon particles and noxious gasses caused by burning fuel underground can account for as much as 40 per cent of the electricity costs of underground mining operations. Recent and upcoming regulations demand a reduction in polluting emissions from mining vehicles and the industry has to respond.

Casper Swart, global product line manager at Atlas Copco explains, "We are currently repairing and retrofitting our diesel engines to meet Tier 3 emission standards. Tier 4 standards will be phased in by 2014. All these modifications have an impact on the size of machines. Engines have to be cleaner, but cleaner engines often means installing bigger components to machines which obviously brings other challenges."

Ryan Lipic of Mining Technologies International (MTI), agrees. "It can be challenging and time consuming," he says, "because legislation is not consistent from country to country. Standards in the US, for example, are more stringent than in Canada but we obviously have to meet all the standards to be able to operate in those countries."

While actual manufacture of a loader typically takes around six months, it takes two to three years to take a product from paper to market. This is largely due to all the testing that we have to go through as well as ensuring it complies with all the necessary legislation."

A PARTNERSHIP APPROACH

The size, type and capacity of machines used in a mine will often depend on the application so a certain amount of collaboration exists between manufacturer and operator in the development and production of underground machines.

"Much of the conversation would be around the application of the mine and the infrastructure", says Mr Swart. "There are mines, mostly copper, with tunnels measuring 4.5m by 4.5m, and you have bigger, mostly iron mines, which have tunnels of 6m by 6m where you can use a far bigger carrying capacity vehicle with a higher profile. Then there's a platinum mine that requires low profile vehicles because their tunnels are five metres by 1.8m. Plus we need to know what kind of infrastructure is available so we can provide the customer with the appropriate solution.

"Whatever the size of tunnel or application of mine, the objective remains the same - to fit the biggest carrying capacity in the smallest envelope. This is essential for maximum productivity."

The pairing of loader and truck plays a huge part in productivity. For example, if a smaller loader is paired with a large truck, it would take many more passes to fill the truck. This results in heavy wear on the loader as well as a waste of valuable production time to get it filled. By the same token, a smaller truck being filled by a loader with a large bucket capacity runs the risk of being overloaded, thus increasing maintenance costs of the truck. The general rule is that three is the ideal number of passes for optimum productivity - so a truck will take three loads from the correct sized loader until it's at capacity. Most manufacturers promote and produce their underground loaders and trucks so they complement each other in this way.

REACHING NEW HEIGHTS

The industry has evolved massively as technology has become more advanced. The increase in the use of LHD automation is one trend that has had an impact on the industry. Without the restrictions that having a human operator in the cab places on underground operations, machines are able to significantly increase productivity levels. Full or partial automation can mean reduced manning costs, fewer loaders in production and ensure a continuous production process.

Joseph Bontje, marketing representative at Caterpillar says safety is the key driver behind the move towards automation. "There are many instances underground when it's not safe to have an operator in the cab," he explains, "so being able to control and monitor machines safely from above ground is critical to operations. Caterpillar's command system is a safe and production solution to having human operators underground. When the safety issue is removed, you can really optimise production."

But while technology has played a major part in increasing productivity, reducing costs and improving safety, so too have customers' expectations grown. Mine owners are looking for the same gadgetry, functionality and capacity that are on surface vehicles – GPS, mapping and localization to name a few. They want to know what the machine is doing in real time – fuel usage, how much muck is being moved, errors in handling etc. These are essential pieces of information that, when put together, help the owner work out ways to reduce the cost per tonne. Manufacturers are constantly looking for ways to incorporate these features into machines already crammed with the standard requirements for health, safety and optimum production as well as innovative ways of being more efficient with fuel. How much further they are able to develop, enhance and improve remains to be seen.

95
The percentage efficiency achieved by electrically driven machines

30
The percentage of energy produced by diesel motors that i used in loading and tramming operations. The remainder is lost as heat energy

40
The percentage of electricity costs that can be expended diluting transmissions of noxious gasses

MANUFACTURING IN A GLOBAL MARKET

Competition is this specialist market is fierce and manufacturers have to work hard to carve their niche. The following organisations are by no means an exhaustive list of the players in the LHD market:

Atlas Copco, based in Sweden, has been providing industrial productivity solutions above and below ground since 1873. Their range of LHDs comprises 13 machines, which includes the Scooptram range of six diesel and three electric loaders, as well as the Minetruck range of underground trucks. The smallest of the Sooptram range, the Scooptram ST2D has a 3.6metric tonnetramming capacity for smaller sized operations, particularly in narrow vein mines.

The largest, Scooptram ST1520 is a 15t LHD for large underground operations. Its low profile means that it can be used in tunnel where the work

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Above: Full or partial automation can mean reduced manning costs

height is as low as 2.7m. The latest addition to the range of Scooptram underground loaders - the Scooptram ST7 - has a tramming capacity of 6.8t, articulated steering and an oscillating rear axle. It is powered by a clean burning, 193 hp 6.7 litre Cummins Tier 3 engine and benefits from traction control to increased loading performance and improved tyre life. The company recently received an order for the 100th sale of the ST7, from Metall Trans LLP of Kazakhstan. Of the future, Mr Swart says "We are constantly striving to meet our customers' needs and we have a few exciting products in the pipeline that we hope will continue to do just that."

GHH Fahrzeuge's product line for underground operations features diesel and electric loaders and diesel trucks as well as niche super low profile loaders for more niche markets, including Russia, Africa and China. They offer a 'plain technology' option for customers wanting a simple solution as well as high tech versions with more sophisticated features. Their loaders transport payloads of between three and 20t, while dump trucks have loading capacities of 15 to 55t. Four wheel drive and articulated swivel hinge are standard features.

GHH's new generation of electric loaders – the LF-10HE, LF-14HE and LF-20HE – are equipped with the GHH-designed Efficient DriveSystem (EDS). EDS is a revolutionary brand new hydrostatic drive line concept. Its advantages include fuel consumption savings, less wear for tyres and brake, highest brake out force and easy handling in one system. The special, active cable drum device helps extend the lifetime of the cable.

Christian Riedel, product manager, says "Not only are our EDS loaders suitable for applications where adaptation for ventilation isn't possible, but they provide increased comfort for the operator and a smooth drive".

MTI's LT series loaders range includes the LT-70, the LT-350, the LT-650, the LT-1050 and the LT 1150. Their latest addition, the LT1650 is their largest loader to date and has an 11 yard bucket capacity. There are plans in the works to develop an even larger truck with a 14 yard bucket.

In addition, MTI built the world's first hybrid diesel electric loader which can operate with low decibel levels and near zero emissions. Its electric motor is powerful enough to perform the tasks of a diesel loader. While running on diesel, it charges its battery for the electric motor, eliminating the need to be stopped to recharge. Noxious gas emissions are reduced by between 40 per cent to 70 per cent, and combined with a high efficiency particulate filter, enables a decrease in breathable combustible dust emissions of 95 per cent. In addition, these decreases could result in a 20 per cent to 40 per cent reduction in the energy required to ventilate a mine. Their DT Series four wheel drive trucks range from 7t to 30t. They offer EPA and MSHA certified engines to provide cleanest air possible, as well as an optional automated lubrication system.

Caterpillar's best sellers are driven by geography and geology. Their smallest loader, the R1300G, and truck, the AD30, are designed for high production in smaller underground mining applications such as those in South America. The biggest machines, the R2900G loader and the AD60 truck, are suited to the larger operations of Australian mines. Caterpillar's underground loaders have payload capacities ranging from 6.8t to 20t with bucket sizes ranging from 2.4m³ to 11.6m³ based on machine and application. Truck capacity ranges from 30t to 60t; body sizes from 11.3m³ to 36.6m³. Sandvik offers a range of LHDs, which includes small models designed for narrow vein and low profile applications, mid sized – for wide variety of mining applications as well as construction tunneling, and high capacity LHDs for mass mining applications. Their diesel and electric loaders have tramming capacities ranging from 1 tonne to 25 tonnes. Three separate low-profile models: the LH205L-M, LH208L and LH209L operate in low profile mining operations with the LH205L-M able to work in back heights as low as 1.6.m. Sandvik's trucks range from the TH320 with a 20t payload capacity, to the TH680, a side-tipping, 80t truck for horizontal underground hauling. All models with payloads from 15 to 60t are designed to operate fully loaded on long spiral gradients of up to 20 per cent at high speeds.

The latest additions to the Sandvik truck portfolio - TH551 and TH663 - were introduced at this year's MinExpo. These trucks are state-of-the-art in their safety and productivity

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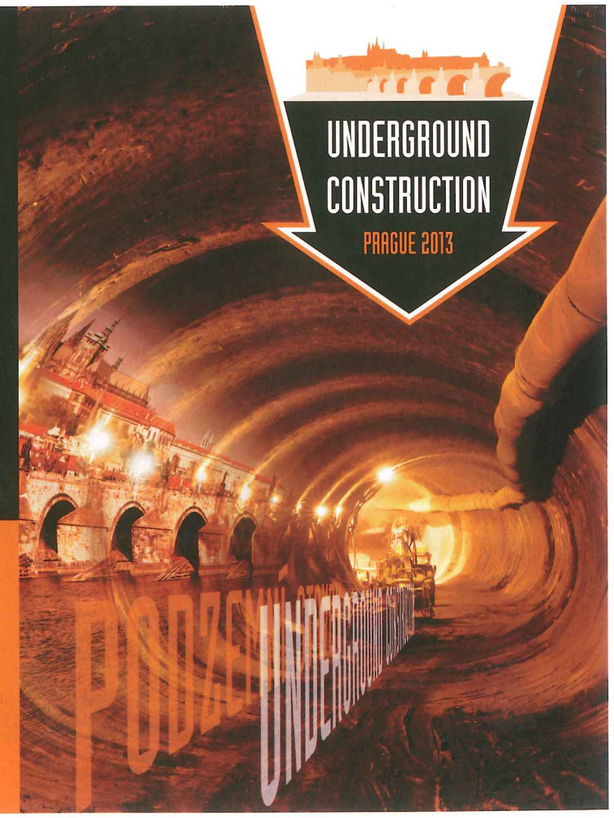

WHICH EVER WAY YOU SLICE IT

Increasingly since the 1980s, contracts in the U.S. and Canada are taking on projects with TBMs and precast segments already procured by the owners. **Gerhard J. Urschitz,** of Strabag and based in Niagara Falls, Ontario, looks at who benefits from client procurement of TBMs

Gerhard J. Urschitz
Gerhard is CEO of the Canadian arm of Austrian contractor Strabag

TRADITIONALLY, TBMS for tunnelling projects are procured by the successful contractor. Occasionally projects are procured with a TBM and precast segments already readily available and contractors are left with no other option than to accept whatever the client has ordered for them to work with.

When clients develop projects where tunnels are involved, usually extensive evaluations are taking place by client organisations, and/or by consultants to select the appropriate tunnelling methods. Upon many other factors, i.e. surface structures, settlement restrictions, site access and length of tunnel, the right selection is also and importantly dependent on the geo-hydrological conditions along the tunnel alignment. Using the principle of the geotechnical baseline report (GBR) is one good and fair approach for clients and contractors, which when applied appropriately, clearly defines parameters and risk allocation.

Once an excavation by TBM is chosen as the method of choice, the discussion starts on how to specify the appropriate TBM and TBM operations. A range from prescriptive to performance based is available. For the purpose of this paper all kinds of hard rock and soft ground boring machines are considered as being TBMs. TBMs are capital intensive investments. However, in relation to the overall cost for a tunnelling project, the costs of TBM and segments are subordinate. The magnitude is dependent on the size and complexity of the project.

Technology and experience with TBM tunnelling advances steadily. Clients, often single project tunnel builders, are typically not at the forefront of latest developments and therefore ask for advice from experienced consultants and sometimes from TBM manufacturers.

Depending on their experience and strategy, consultants will offer to their client's procurement methods that they consider most suitable and in compliance with the specific country procurement law. Specifically in regard to TBM selection these can include the following scenarios:

- Client describes the geology and associated parameters (i.e. GBR) – contractor is left to choose the right tunnelling machine;
- Client describes geology and associated parameters (i.e. GBR) and specifies the type of TBM to be used – contractor to negotiate with TBM manufacturers exact configuration;
- Client describes geology and associated parameters (i.e. GBR) and defines the exact type and configuration of TBM – contractor to choose from pre-selected TBMs and negotiates last details and price with TBM supplier;
- Client chooses and purchases the TBM, contractor is given the TBM to operate;
- Client chooses and purchases the TBM; ownership of the TBM is transferred to the contractor once awarded the contract;
- Client involves pre-qualified contractors in an interactive process to find the most appropriate TBM, contractor to order TBM that partially or greatly reflects his understanding and input provided;
- Client involves pre-qualified contractors in an interactive process to find the most appropriate TBM and purchases the TBM in advance of contractor selection, contractor is given the TBM to operate;
- Client involves pre-qualified contractors in an interactive process to find the most appropriate TBM and purchases the TBM in advance of contractor selection, ownership of the TBM is transferred to the contractor once awarded the contract.

In all cases clients are the combination of project owners and their associated and specialised consultants. It shall also be mentioned that in all cases TBM manufacturers/suppliers are involved more or less extensively in the process to advise clients, consultants and contractors. In some cases, TBM manufacturers also have been pre-qualified before entering the process.

Clients are left with the decision on how to proceed.

This paper specifically concentrates on options, where clients decide to get involved in the procurement of TBMs ahead of contractor selection and award.

CASE HISTORIES

With one exception in 1972, where one transit project in Australia started with the direct procurement of a TBM, it can generally be stated that the client procurement process started in the late 1980s, with a variety of projects, including mining, water, rail, nuclear waste and subways.

While the references of Table 1, right, are the result of an international review of publications, project reports and questionnaires it cannot be concluded that the list is comprehensive.

What can be seen from the project summary is that the majority of projects are rail/subway/metro projects (nine out of 17), and the major TBM type used for owner procurement is the EPBM (30 out of 43), which relates to more difficult soft ground conditions.

It seems that transit authorities, mining companies and wastewater companies with usually a network of tunnels to be built are amongst the potential applicants of the owner procurement method for TBMs. Only few single project entities.

One special case, which is not mentioned in the table and that does not completely fit into the categorisation, is the City of Edmonton. The City purchased eight EBPMs and decided to operate them by themselves. In this case the City is owner and contractor in one entity.

Geographically it is interesting to note that some nine out of 17 projects / clients (53 per cent) are based in North America, followed by China with a share of 23 per cent. None of the projects are located in Europe.

1972
The year that saw the first direct procurement of a TBM by a client

STAKEHOLDERS IN THE PROCESS

In the owner procured TBM process the following are the major interested stakeholders:

- Client
- Consultant
- Contractor
- TBM Manufacturer

Each of the stakeholders has certain priorities that need to be considered during the decision making process.

CLIENTS

Clients have the task to implement a project or a network of projects. Their priority is to carry out the projects within schedule and budget. Specifically tunnelling projects are associated with risks due to unanticipated ground conditions.

Priorities for clients in regard to TBM procurement are:

- Potential acceleration of the project implementation once financing has been secured and the construction contract can be awarded
- Stay within schedule and budget
- Minimise risk during implementation (by specifying as much as necessary)
- Create a competitive bid environment (maximise qualified

Table 1. Reference Projects for Owner Procured TBM Projects

Project name	Client	Location	Type	Spec	Year
Melbourne Rail Loop	Melbourne URL Authority	Australia	Rail	6.85m, 4x2.8km	1972
Stillwater Mine	Stillwater Mining Company	USA	Mine	4.1m	1987
London Water Ring Main	Thames Water Authority	UK	Water	2.95m EPBM, 1.8km	1991
St. Clair River Tunnel	Canadian National Rail	Canada/USA	Rail	9.5m EPBM, 1.8km	1992
Lower Kalamazoo Mine	Magma Copper Company	USA	Mine	4.6m, 9.7km	1993
Nuclear Waste Repository	U.S. Department of Energy	USA	Nuclear Waste	7.6m, 7.3km	1994
Rio Subterraneo	Aguas Argentina	Argentina	Water	4m EPBM, 15.2 km	1995
Shepard Subway	Toronto Transit Commission	Canada	Subway	5.9mEPBM, 2x3.9 km	1996
Stillwater Mine	Stillwater Mining Company	USA	Mine	2x4.6m, 2x5.6 km	1996
Changi Metro	Land Transport Authority	Singapore	Subway	6.1m EPBM, 3.5km	2000
Singapore Downtown Line	Land Transport Authority	Singapore	Tender for 10 TBMs		2008
Spadina Subway	Toronto Transit Commission	Canada	Subway	4 EPBMs, 2x8.6km	2009
Shanghai River Tunnel	Shanghai Highway Authority	China	Highway	Mixshield	2010
Downtown Line, Stage 3	Shanghai Metro	China	Subway	EPBM	2011
Southeast Collector Truck Sewer	York Region	Canada	Sewer	3.5m, 2x2.5km, 2x5km	2011
Metro Fortaleza	Metrofor	Brazil	Metro		2012
Eglinton Scarborough Subway	Toronto Transit Commission	Canada	Subway	5.75m, 2x6.2km	2012

Source: ICD Research Industry Survey 2011

Table 2: Pros and cons of advanced TBM procurement

Party	Advantages	Disadvantages
Melbourne URL Authority	- Build up of know-how (system projects) - Specification according to client 'wants' - Potential early start of tunnelling - Higher certainty on delivery schedule of TBM - Control over TBM costs - 'Risk transfer to contractor' - Economy of scale for multiple TBM procurement - Reduced TBM contingencies in contract price - Longer TBM procurement period - Attraction of smaller less qualified contractors - Centralisation of spare parts	- Early capital investment - Risk on selection of 'right' TBM - Wear and tear risk (as specified) - Build-up of detailed know how - Client left with TBM or small buy-back value - TBM overspecified - Interface client/supplier/contractor - Standstill and delay risk - Dependence on consultants - Client left with TBM but no project - Responsible for all TBM related problems - Maintenance/production trade-off by contractor - Marketing efforts of TBM suppliers (unique features)
Stillwater Mine	- Substantial additional efforts (specification, process) - Increased site managements/control function - Build up of expertise/special advisor package	
London Water Ring Main	- No advance financing of investment - Reduce efforts for advanced works - Claim potential when problems with TBM - Typically no TBM ownership after completion	- No utilisation of inventor plant and equipment - Loss of competitive edge (based on experience) - Loss of or reduced influence on configuration - Reduced revenues (smaller project size) - No direct contact with TBM manufacturer - No/reduced input of experience - Risks for TBM without or limited involvement - Refurbishment risk - No/limited input on work flow on TBM - Contractor's role reduce to TBM driver
St. Clair River Tunnel	- Negotiation with client organisation - Early involvement with client - Bulk procurement - Higher security on payments - Higher level of requirement	- Contract with client/used by contractor - Performance bond requirements

Source: Gerhard Urschitz, Strabag

number of contractors)
- Increase certainty during tunnelling (high quality TBM by 'over'-specifying the TBM)
- Build-up of experience (in cases of system or multiple implementations)
- Try to get the best machine available for the expected project conditions

CONSULTANTS

Consultants have the task to advise clients in regard to procurement strategy and design projects technically. Their priorities include:

- Extended involvement in advising clients and managing projects during design and implementation
- Build-up of TBM experience
- Using experiences from previous projects

CONTRACTORS

Contractors are typically the entities that get involved after all strategic decisions have been taken. They are 'confronted' with project and procurement documents developed by clients and their consultants. Contractors' priorities include:

- Provide a competitive and best offer (by minimising knowledge transfer and maintaining a competitive edge)
- Utilise and build-up on experience gained from previous projects and thereby maintain the competitive advantage
- Utilise inventory as appropriate (TBM, trailing gear, conveyor belt system, rolling stock, supply lines, rails, etc.)
- Want to know (specify) or be involved in the TBM selection (open vs. double shield; EPB vs. slurry)
- Be in charge of TBM configuration and operations

69.7
The percentage of client procurement projects that are for EPB machines and in difficult soft ground conditions

- Receive contract based on qualification and experience

TBM MANUFACTURERS

TBM manufacturers are to provide appropriate machines for anticipated projects. They are active worldwide. Due to the specialised technology there are only a very limited number of TBM manufacturers available. Sometimes they are involved in early discussions with clients and or consultants, where they try to sell their technology.

Often the influence of this early involvement is reflected in tender documents by including specific features which are unique to one of the manufacturers (e.g. movable cutterhead, specific grouting concept).

They are on the forefront of developing new tunnelling technologies with their in-house resources as well as in cooperation with contractors by specifying particular features.

Depending on the geographic location of the project the following factors need to be considered:

- Cost of labour
- Availability of experienced labor
- Time for delivery of spare parts

The level of mechanisation depends

on above factors, the higher the cost of labour the more effort has to be put into the TBM design and configuration to limit the scale of labour on the TBM (e.g. optimised logistics concept, automatic anchor drill unit).

Another feature that has an impact on the TBM and trailing gear layout is the mode of muck removal.

CLIENT-PROCURED TBMS

When considering the specific circumstances of each project, there might be situations where it can be beneficial for clients to apply the advance procurement process. Before analysing such circumstances, a general view is provided outlining specific pros and cons for each of the major stakeholders in the process. A summary of pros and cons is provided in Table 2.

CLIENTS

Decision making processes specifically within public entities (e.g. transportation authorities) usually follow a long path. From the project idea to implementation it often takes decades until all pieces of the puzzle are in place to finally start construction. A main reason for delays and uncertainty is the funding of these very capital intensive projects. Once the funding is secured the projects ideally should start immediately and be finished in the shortest time possible to make the infrastructure available to the public. This reason, the earlier start when the TBM is already readily available, is found to be the major argument for the client procurement process. It does, however, only hold true when the advance works have been completed to an extent that tunnelling can start within a short period of time. Often projects require the construction of access points, e.g. shafts, portals and assembly caverns. before the TBM can finally be assembled. With a lead time of 10 to 12 months until the TBM would be on site when using the 'traditional contractor procurement this benefit of early TBM start can be diminished when the advance works are not completed in time.

The advanced TBM procurement option has been used as political measure. Once one or even more TBMs have been ordered (and paid for) the motivation to continue a project is higher than otherwise. Experience shows that politics are sometimes not impressed with such facts, especially after elections, which result in new governments, and still question, stall or cancel the process. The Shepard and Eglinton Line advance TBM procurement in the early 1990s is such a case where

53
The percentage of client procurement projects located in North America

0
The percentage of client procurement projects located in Europe

it was decided to cancel or substantially defer the project after the decision of early TBM procurement had taken place.

Another major advantage has been seen by some public transport agencies (e.g. Singapore Metro) where it is expected that 10 TBMs of similar configuration will be utilised to implement the Downtown Line. Combined with the above statement of an accelerated implementation the argument of bulk procurement has been used. When various contractors would purchase 10 TBMs separately the price for the Authority would most likely be higher.

In order to get involved in such detailed negotiations with TBM manufacturers, client organisations need to be prepared to mobilise accordingly and have sufficient experienced staff available. This staff would of course be supported by consultants that provide the specific advice, but clients usually do not like to be dependent on external experience only.

For clients with only one tunnel project this approach has therefore to be questioned. It only is worth the effort when a series of tunnel projects are planned to be implemented within a certain period of time. Pressure to cut cost on public entities counters this approach though.

Once the client staff has gained the experience, it can define the TBM and all its features that it finds most appropriate for the project. Clients have to be aware that when following this trail risks are taken over that are usually allocated to contractors. Clients have to be aware that it is 'their' machine and that all costs associated with any type of changed conditions, poor performance and resulting standstills and delays have to be compensated for.

This statement extends also into wear and tear costs, when kept within the client risk portfolio. Various forms of risk sharing and ownership transfer have been seen already, including transfer of risk back to the contractors e.g. contractor involvement in TBM selection process, TBM ownership transfer to contractor once construction contract has been awarded, or transfer of performance risk to the contractor. The risk budget allocated in the contract price by the contractor will depend on the fairness of the contract and on the allocation of risk. For example, it shall be mentioned that contractors will price the risk when confronted with TBM ownership or performance risk where no or limited input was provided.

Another reason to use the advance procurement of the TBM is the risk management by clients in difficult ground conditions. There have been projects that failed due to the selection of the wrong type of TBM or the wrongly equipped TBM. This problem can be overcome by specifying exactly

"Advanced TBM procurement has been used as a political measure. Once a TBM has been paid for, the motivation to continue is higher"

what the contractor has to use, or to pre-purchase the TBM. Clients have to be aware that while actively managing this risk by 'interfering' with the process, they are taking on the risk themselves. The question remains who has more experience and who is in the better situation to handle this risk.

One interesting argument for the owner TBM procurement is the statement that clients can expect more competition for their projects when the costs for the TBM (and segments) have been taken out of the scope, thereby reducing the contract amount. It is expected that more contractors would qualify or even apply for qualification, when already provided

with a TBM and segments. This might partially be true when considering limited bonding capacity of contractors, but has to be questioned generally.

A client should look for financially sound and experienced contractors rather than trying to maximise the pool of interested parties and thereby running into the risk of default situations during construction. Defaults can come from financial difficulties, when projects run into technical/contractual problems but also from technical problems when less experienced contractors are given a TBM to excavate a tunnel that experiences technical challenges. It sounds more like a compromise where a potentially lower price is traded off for less experience and financial strength. In order to compensate for such problems TBMs are likely to be over-specified to cater for all eventualities.

Private clients (e.g. mining companies) have a different interest in the TBM procurement process. They usually want to stay in charge of the technical development of the machines and therefore often get involved intensively in research and developments of new machines or features. They are looking for contractors to install 'their' machines and operate them.

CONSULTANTS

Consultants can be seen as the group that gains most out of this process without taking on substantial risk. Extensive involvement to advise clients in early phases, build-up of experience to be able to provide the highly specialised services, preparation of all specifications and documents for both procurement processes (TBM and construction), detailed design services for the segments (which would otherwise be carried out by the contractor), and increased involvement during construction to verify/justify their early decisions and configurations can be seen as their benefits.

A very high level of expertise and experience is required to be able to provide these services. Naturally, only few consultants will be able to cover all the tasks, resulting in a situation where competition for the consulting services is very limited or these services have to be outsourced.

CONTRACTORS

Contractors are faced with an unusual situation when being involved in a project where the TBM and segments are provided and their input in the decisions has not been given or is very limited. It can be seen that contractors are reduced to 'operators for pre-purchased TBMs' and projects and specifically clients cannot gain from their experience.

In addition to the arguments mentioned already above, difficulties can arise out of the interface and relationship between client/TBM manufacturer/contractor, where often no direct contact between contractor and TBM manufacturer is allowed. Contractually this situation is understandable, but in the sense of partnering, team work and cooperation it is very detrimental to the cooperation of the parties. Assembly and start-up of the owner procured TBM by the contractor involves risks as well, specifically when not guided by the manufacturer. It is a difference whether assembling and starting up once own TBM or the client owned TBM.

53
The percentage of early TBM procurement projects that are rail or metro

Tunnelling contractors have a vast experience with all different types of tunneling methods and have built-up in-house knowledge (technical departments), whose task it is to look at every project and optimise the TBM, trailing gear, segment production and site installation. Their job in the advance procurement situation is reduced to supervise the assembly of the pre-purchased TBM. Any modification to the TBM and trailing gear is usually challenging due to the ownership of the TBM by the client, and due to the inherent risk transfer. Even a change from rail bound mucking to conveyor belt mucking is usually not possible, or requires a substantial effort.

Contractors like to be in charge of the tunnel production including logistics and operation of the various activities on the TBM. Optimisations resulting from experience gained elsewhere cannot be utilised. This includes potential mechanisations of activities (e.g. rock bolt drilling, or grouting) to reduce manpower on the machine.

To also mention positive aspects in the vie of the contractor, the reduced advance financing requirements, no obligation to re-use or sell the TBM after use or the more 'leaned-back' attitude can be mentioned. Eventually, the TBM has to work as specified and the contractor is such situation would still put all the effort in to make it work.

TBM MANUFACTURER

TBM manufacturers get involved very early in the selection and specification process when the TBM is procured in advance. On one hand their substantial input is required to specify the appropriate machine and features, on the other hand they want to make sure that their machine is the one to be used.

Negotiating with client organisations might be different than negotiating with experienced contractors. While clients want to make sure that the TBM will work under any circumstance and will therefore be receptive to additional features, contactors will optimise the use of 'bells and whistles' to stay competitive. Clients will intuitively specify and order a higher quality TBM with a conservatively rated power, maximum torque and thrust and include duplicate elements to minimise or even eliminate downtime.

One of the disadvantages mentioned by manufacturers was that performance bonds are usually required from clients, what manufacturers are not used to provide. This puts an additional financial burden on these organisations.

> "Consultants can be seen as the group that **gains the most** out of this process without taking on substantial risk"

TBM manufacturers usually have performance criteria to fulfill as part of their contractual obligations towards the client. These performance criteria (e.g. minimum penetration rate) are usually not part of the requirements put towards the contractor.

REASONS AND CRITERIA

Based on the findings above, criteria shall be developed to outline situations where it is beneficial to use the client procured TBM process. Due to the many and substantial disadvantages as shown it can be clearly stated that this procurement process cannot and shall not be used on any standard project.

Reasons for a potential successful implementation of this process can be:

- Accelerate construction schedule
- Bulk procurement of multiple similarly specified TBMs
- TBM configuration according to client specification
- Risk management or risk sharing

There are criteria associated with these reasons which have to be considered. One main criterion is that client organisations have to be prepared to seriously build-up in-house expertise and not only rely on consultants' opinions. There has to be a clear understanding of technology, specification, processes and alternatives available in order to guide the team to the desired outcome. Also, clients have to be aware and prepared for taking the risks involved. Transferring the risks back to the contractor is detrimental to the process. Another general criterion is that the geological/geotechnical and hydrological conditions have to be well known in advance. Only once these conditions are as clear as possible, can TBM selection can follow.

CONCLUSION

When seen from a distance it appears that the client TBM procurement method will benefit the clients greatly due to early selection and a more timely process. The client gets what it wants.

Once the client starts with the procurement, considerable risk is taken on, which is usually a contractor risk. Clients have to be aware that they take on the full responsibility on the capabilities of the TBM and on any additional costs due to changed ground conditions if the TBM cannot cope.

Rather than taking away responsibilities from contractors by pre-purchasing the TBM including segments, clients shall put more effort into pre-qualifying both financially and technically capable contractors, especially on demanding projects. Very few circumstances remain where the client procurement process eventually provides a benefit to the project. Mainly the schedule gain, but also bulk procurement benefits for networks of projects.

Geographically the client TBM procurement method seems to appear mainly in North America and parts of Asia. One could argue that there are specific circumstances that would motivate clients to separate the TBM procurement from the contractors. These circumstances could include lack of 'trust' in anticipated experience of local contractors, and the opinion of consultants. It is interesting that to date there are no cases of client procurement found in Europe

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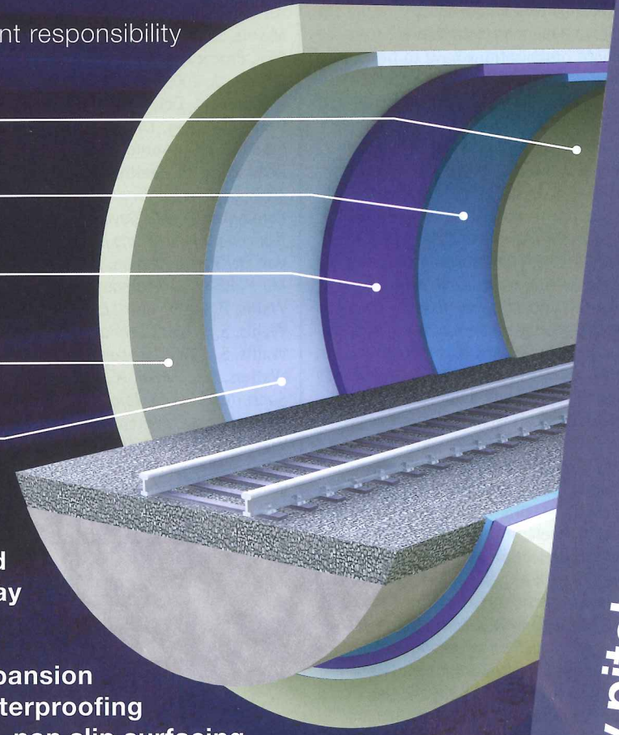

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ULTRA RAPID UNDER PASS

URUP, AN abbreviation for Ultra Rapid Under-Pass, was originally intended as a method to bore tunnels passing under roadways or railways in order to technically differentiate Obayashi in the ever more competitive global and domestic tunnelling markets. Dr. Kanai questioned the necessity of access shafts designed for the purpose of launching and receiving TBMs. He set a target to reduce tunnelling costs and periods by 30 to 50 per cent compared to conventional methods which consist of shafts, tunnels and cut and cover sections, along with a 50 per cent or more reduction in carbon. In order to achieve this, he decided to eliminate both launching and receiving shafts at the same time by developing a

URUP is a shaftless shield technology. The TBM is launched and arrives at ground level and drives under shallow cover without ground treatment. The result is significant cost savings, reduced construction time and reduced environmental impact. The technology was presented at the September 2012 BTS meeting by **Makoto Kanai** and **Akihiro Nishimori** of Obayashi

URUP allows a low-impact drive to be executed under shallow cover

boring system which allows operations to be undertaken with shallow cover and without causing ground disturbances.

EXPERIMENTAL PROJECT

Obayashi initially carried out an experimental shaftless tunnel at their R&D Institute where a 100m long bore with cover ranging from 0.65m to 2.2m was constructed using a prototype rectangular shield equipped with an excavation width of 4.8m and height of 2.15m. Obayashi confirmed the feasibility of the system by developing a valid lining design under very shallow cover. Management of face stability and ground settlement control has been improved through accumulated knowledge and re-applied over actual projects.

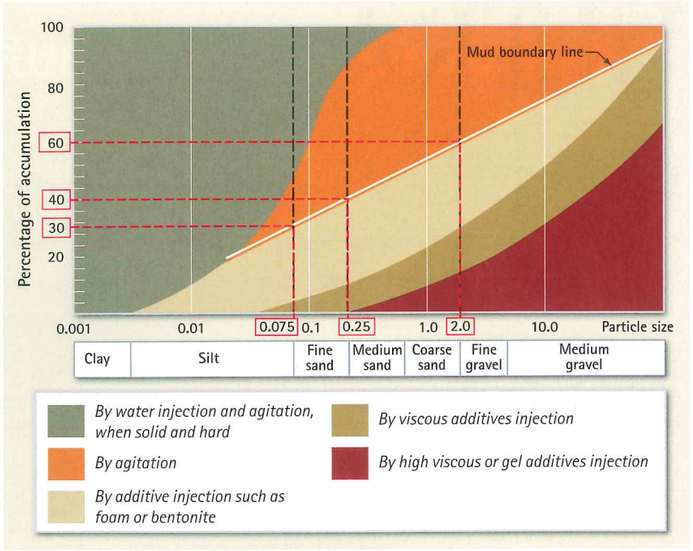
During this experiment, ground settlement was successfully reduced to 10mm or less, even with cover as small as 0.65 to 2.2m. The use of hardened backfill material was also questioned around the circumferential and homogeneous portions. These were replaced with pressurised and fluidised excavated muck. This replacement was important to the stabilisation of the cutting face in the circumferential direction during TBM advancement.

METROPOLITAN EXPRESS-WAY ROAD TUNNEL

In 2008 Obayashi was awarded to a design and build (D&B) contract for a 13.6m diameter road tunnel project using the system. The tunnel was driven through 895m of soil composed of very soft marine clay and loose sand with a cover of 0 to 25m. The maximum ground settlement observed was 5mm. The TBM started its outbound bore from the surface to a turning shaft over 550m away, it was then turned in the shaft and set on its return bore back to the surface in the opposite direction over a length of 345m.

METROPOLITAN RING ROAD TUNNEL

The second project was also a D&B for two 392m twin road tunnels with a cover of 0.6 to 4.6m. The TBM had a section 11.96m wide and 8.24m high. To accommodate the lining configuration, a hybrid-arch shape was chosen for economical design with an optimum thickness of 400 to 500mm. The geology at heading was a very stable loam soil for the upper half, and gravels and cobbles situated above the ground water table in the lower half. Therefore Obayashi selected an open type TBM with mechanical excavators. A monorail-mounted erector was newly developed for rapid assembly of the lining segments as well as for its reusability for any shaped tunnel sections (circular, rectangular or oval).



Above: Figure 1, Additive selection chart

Opposite, above: Figure 3, Long term testing of sealing material

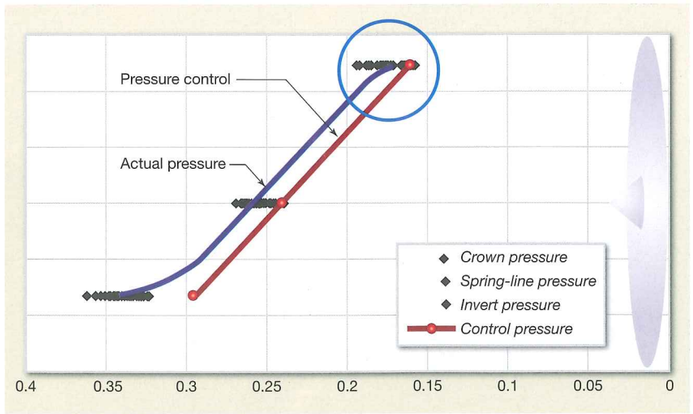
Below: Figure 2, Proper face pressure

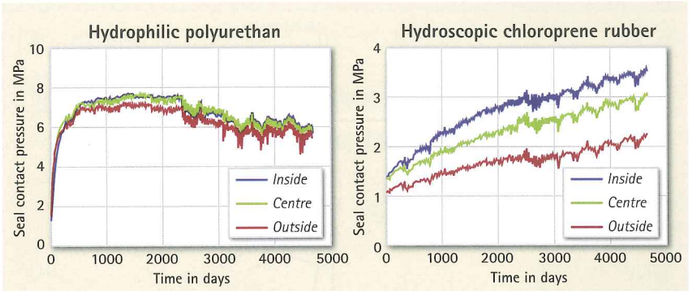
The TBM started its boring with a cover of 2.2m below a quiet residential area.

The TBM appeared at the first exit portal 400m away and then its direction was changed for the 400m return-trip. The thrust reaction of the supporting frame was rather small due to reduced thrust forces. Furthermore the distance between the twin tubes is only 200mm.

The TBM reappeared at the starting point after successfully boring under a cover of 1.2m with maximum ground settlement of only 10mm or less. The traffic above the tunnel was uninterrupted throughout the entire duration of tunnel construction work.

A single belt conveyor unit was implemented to transport the muck back through the first bore while excavating the return tunnel by enabling right angle turning belts, which simplifies conveyor belt start and stop control as well as its emergency control.





SLIP ROAD TUNNEL FOR NEW INTERCHANGE

The third project was another D&B slip road tunnel for a new interchange composed of multiple 70m bores, each with a cover of 2.8m to 10m under a heavily congested highway. The ground settlement was only 3mm or less. The geology at heading was composed of compacted medium sand due to the existence of an old embankment.

In this project the experimental prototype TBM was re-used four times for bottom and side bores. For the top bores an open-face TBM was used due to the large amount and size obstructions encountered; such as steel sheet piles, concrete blocks and boulders.

The TBM first bored two bottom horizontal tunnels, and then two side vertical tunnels and finally two top horizontal tunnels to create space for the construction of an RC under-pass lining, followed by removal of trapped soils from the tunnel and temporary steel lining segments.

CROSS HARBOUR GAS PIPE LINE TUNNEL

The forth project was another 1,080m D&B gas pipeline tunnel, crossing a bay with excavation diameter of 2.13m and cover of 0.8 to 23m. The ground settlement was only 5mm or less. Thanks to the omission of shafts, the project was completed five and a half months ahead of the original program. More importantly, the following work of gas pipe installation was also eased by an increased length of gas pipes and a reduced number of welds.

ESSENTIAL TECHNOLOGIES

URUP is based on the five following key elements supporting the system. These elements minimise disturbances to soils above a tunnel while maintaining high levels of productivity.

ADDITIVES

Firstly, it is important to select the optimum additive to ensure fluidity of excavated muck in relation to the particle-size distribution at the heading. Obayashi uses a variety of additives such as: mineral, surfactant (foam), water soluble polymer, and water absorbency resin depending on soil properties at heading. As additives are important in making the excavated muck plastic, the proper additive should be selected in terms of the soil and ground water level.

FLUIDITY

Secondly, it is important to monitor and maintain the fluidity of excavated muck in the pressure chamber in order to keep the cutting face stable. Although the state of fluidity is invisible, a remote sensing and data back analysis technology was invented which provides computerised visual output. In order to monitor the plastic flow continuously, rods with rotary vanes were installed in the pressure chamber. The rod rotates in the chamber as the shield advances, and the rotation torque is measured. The measured torque is immediately back-analysed, enabling real-time visualisation of the pressure chamber fluidity. It enables assessment of the area and degree of not-flowing solid muck in the chamber.

13.6
The diameter of the first URUP tunnelling project in Japan

Based on visual information, the necessary volume of the additive will be injected into the most critical areas of the chamber from both the bulkhead and the cutting spoke to improve the fluidity. Additionally, a rotary agitator and fixed agitator rod are installed at the center of the TBM and at the back of cutting spokes and bulk head for optimised agitating. The most appropriate chamber configuration can be designed using this system, thus minimizing obstructions from lack of muck fluidity.

FACE PRESSURE

Thirdly, another prerequisite is control and maintenance of face balancing pressure at both the front and around the circumference of the TBM.

Earth pressure theory will help to determine a provisional control pressure for face stability during initial advancement. In theory, the lateral pressure is normally separated into a hydrostatic pressure portion and an effective earth pressure portion. For face stability, earth pressure at rest should be incorporated in the face control pressure to minimise disturbance to soils above tunnel. In addition, it is always recommended to provide at least two trial advancement sections whereby soil deformations, movements, earth pressures and pore pressures are monitored to verify or modify the provisional control pressure.

The optimum balancing pressure in the chamber shall be specified by carefully modifying surplus pressure. In the experimental case as documented by Obayashi, a surface settlement of some 6mm at an initial stage was improved to only 3mm by slightly increasing the surplus pressure.

The TBM operator usually pays attention to pressures at the screw conveyor tip-toe for a smooth discharge of excavated muck in order to maintain a higher rate of production.

This often results in a fall of pressure control at the crown followed by ground subsidence once the TBM's tail has passed. In an adequate operational situation, the actual face pressure at the crown level to the invert level is slightly higher than control pressure line, resulting in minimum ground settlement. This is Obayashi's standard for EPB tunnel boring.

BACKFILL

Fourthly, in order to prevent ground settlement it is important to concurrently backfill circumferential void while boring. The technique consists of backfilling, by replacing the pressured fluid muck filling circumferential void by a watertight homogeneous self-hardened material as the TBM advances. Cement-bentonite is normally used with a coagulant mixed in just before injection which hardens afterwards, forming a watertight layer.

Dr. Kanai prefers injection from lining segment to injection from the TBM tail plate, as long as it is injected simultaneously and concurrently with the advancement of the shield.

From experience gained on the 12m shield tunnel projects, no difference was observed between both types of backfilling method, resulting in a minimal ground settlement of 3 to 5mm throughout the 2,000m bore in sandy soils. Another noticeable finding is that a 20 to 40mm layer of consolidated muck proves a valid replacement of backfill material for fluid excavated muck when used in conjunction with a proper backfill material and with a proper backfill method.

From previous experience of slurry shields, back in 1984, where the same material and injection method were used, the ground settlement was also observed to be only 3 to 5mm.

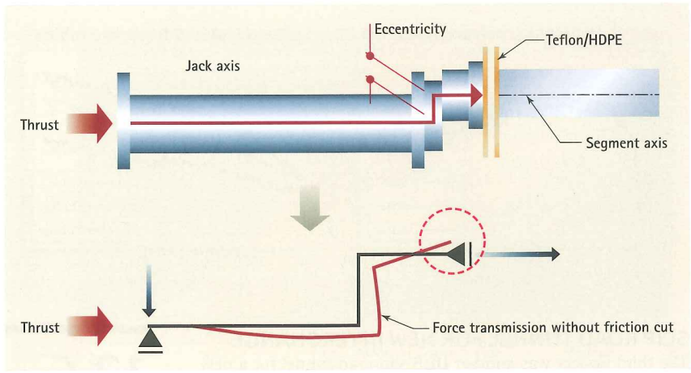
In this project, an interesting observation was made whereby a 7 to 8mm mud cake of bentonite and sawdust mixed in slurry appeared in between hardened backfill and surrounding soil. It is assumed that the circumferential and homogeneous portions are replaced by self-hardened backfill materials from pressurised slurry for face stability during TBM advancement.

RIGID JOINT AND WATER TIGHTNESS

Additional attention should be paid to prevent deformation of assembled segmental lining and consolidation of surrounding soils due to water leakage through the lining. Obayashi has developed a bending rigidity controllable joint system for lining segments. While enabling a one pass assembly for a higher productivity it also includes technology ensuring watertightness of both segment bodies and segment joints.

RIGIDITY CONTROLLABLE JOINT

The bending rigidity controllable joint system for lining segments (called 'horizontal cotter joint') was invented by Obayashi. Where the soil around the tunnel is soft and the ground settlements is a critical issue, pre-stress forces can be introduced in the joint automatically during segment assembly work, resulting in minimum deformation of the lining.



Above: Figure 4, Friction cut plates form a key part of the URUP system

The joint mechanism is characterised by high and equal rigidity both inward and outward bending moments which enable an economic design of joint bending rigidity control. Additionally, the joint system offers higher durability, increased water tightness due to pre-stress forces applied to a sealing material, and a smooth inner surface without recesses such as bolt boxes.

Therefore it enables sewer tunnels and flood reservoir tunnels to be designed without a secondary lining even though they undergo extreme internal water pressure. Furthermore, the joint consists of a one pass assembly system which enables rapid erection. This assembly system does not require bolt fixing works; therefore it reduces assembly cost and improves safety significantly.

HF-SFRC LINING SEGMENT

Steel fibre reinforced precast segment with highly fluid concrete were developed with simplified steel rebar caging in order to produce a watertight and durable lining. The highly fluid SFRC lining segment excels in tensile resistance as well as in compressive resistance, and also excels in bending/shear resistance and ductility.

The stress distribution effect by steel fibres reduces crack width and provides higher durability. In addition, the steel fibres are effective in reducing the spalling of the concrete lining, therefore it provides an improved performance in terms of serviceability.

WATERTIGHT TUNNEL LINING

In Japan, hydrophilic polyurethane and hydroscopic chloroprene are used as typical seals in segment joints. These are water reacting and expanding materials for reliable and durable watertightness.

Obayashi has been studying a long term sealing behavior for both sealing materials for the last 13 years and intend to continue until the testing apparatus breaks. The test will highlight the differences in water reacting performance such as water reacting mechanism, water absorption speed, and water stopping mechanism.

The polyurethane type absorbs water if exposed to ingress and discharges water when it is dried, therefore it is reversible. The chloroprene type also absorbs water but it does not discharge water.

The durability of both materials is equal. These materials would damage segments if the swelling pressure is high, therefore attention should be paid to sealing design.

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DAMAGE PREVENTION TO LINING SEGMENT

The lining segments would be damaged by thrust jacks during excavation. The centroid eccentricity of the thrust jack induces a radial expansion force which is the major cause of lining damage. Obayashi has invented the friction cut plates which are attached to the jack spreaders.

The twin plates decrease the ring radical expansion force to the lining and dramatically reduce cracks in the lining.

APPLICATION OF THE JOINT SYSTEM

The joint system was first applied to a large bore flood diversion tunnel with an external lining diameter of 11.8m under a hydrostatic pressure of 0.6Mpa.

The tunnel lining has to bear external earth and hydrostatic pressure constantly, as well as internal water pressure during flood diversion. The tunnel, without a secondly lining, achieved a long-desired watertightness even under hydrostatic pressure of as high as 0.6Mpa.

After the project, this joint system was applied to a lot of projects such as Road Tunnels, Utility Tunnels, Reservoir and Sewer Tunnels, and Metro and Railway Tunnels as well as URUP tunnels with various hydrostatic pressure.

Watertightness in all of the tunnels is quite well maintained and quite well controlled.

Questions from the floor

When you were driving your shield, did you use any bentonite injection to reduce friction?
We do not inject bentonite to reduce friction. It is only used to improve the fluidity of the excavated muck. We injected bentonite only at the front of the machine, not around the machine. But it is important to maintain the circumferential stability.

Are there any difficulties with steering rectangular shaped TBMs?
No. Not in our experience, we are always able to check that there are no problems. It can be applied to rectangular shape as well as circular shaped TBMs. Even if the machine is rolling, we can control it by manipulating the direction of the twin cutter rotation. If the pitching or rolling is of concern, I recommend adding extra weight to the erector to balance the forces. In addition the friction cut plates on jack spreader are effective for controlling rolling.

If you have a fire in your tunnel, how would you repair the damage to the important seals around the concrete segments, especially if they are subjected to hydro static pressure?
Generally, we use fire resistant panels or sprayed fire resistant materials that can be shot creating layer up to 50mm thick. Obayashi has developed a fire-resistant lining by mixing 0.2 per cent polypropylene in order to avoid explosive spalling of concrete. Based on the fire test results of the joint in the fire-resistant segments, the temperature at the depth where the sealing material is embedded does not rise beyond the limit that compromises its integrity.

How many grouting points you have in the lining?
Each ring has two injection points. In Japan, many engineers prefer to inject from the tail plate, but I recommend injecting through the lining. It is because injection from the tail plate requires many pipes on the plate. It causes the deformation of the tail plate if the pressure is too high or constructing a tunnel of curved alignment. Furthermore, the deformation of the tail plate may cause lining segment damage.

What kind of design life does the sealing system allow for – what is the watertightness in the mentioned flood tunnels without a secondary lining?
There are two sealing systems, one is a gasket type and the other is a hydrophilic type. The hydrophilic type is more preferable for design as it allows for ground deformation due to seismic action thanks to its flexibility and water absorbing system. From experience gained from the Tokyo Trans Bay Highway Tunnel project where the rigidity controllable joint system was not used, only a small quantity of water leakages were observed. From experience of Underground Aqueduct Tunnel Project where the rigidity controllable joint system was adopted with same sealing material and under same hydrostatic pressure of 6bar, no water leakages were observed. The joint system is quite effective for watertightness. The design life of this system is 100 years.

How do you consider the risks when trying out the new technology?
We have not faced any problem in this technology to this date. If the ground settlement exceeds 5~10mm, we will repair roads and rail tracks by re-paving or infilling with ballast. During the development period, we had other mitigation measures such as side cutter and multiple boring systems. However they were quickly dismissed because we found the TBM can excavate without inducing settlement as long as fluidity is maintained amongst other criteria. Therefore I think the risk is technically the same level as another tunnelling method. In addition, Obayashi spends around GBP 100M (USD 149M) per year on research and development and there are plans to further increase in the future.

100
The amount in GBP millions that Obayashi spends on research and development as a company

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 July 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*.
awards@tunnelsonline.info

Dr. Kanai concluded his presentation with an emphasis on the importance of persistently believing in oneself. We have the ability to make new ideas into practical technology

■ *Rapporteur: Akihiro Nishimori*
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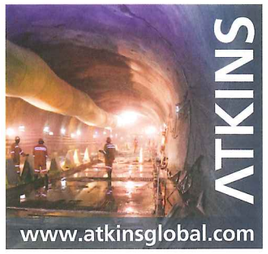

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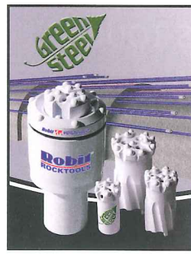

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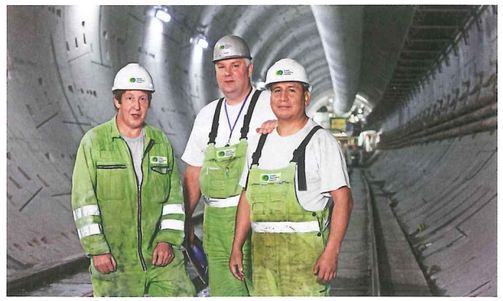

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www.ita-aites.cz/en/conference_underg_constr/conference-uc-2013

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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 in a country currently seeing a boom in infrastructure development.
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

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

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

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.

Tunnel Operators Forum
17-18 April 2013
The twice yearly UK operators forum. Hosted at the IMechEng.

Harding Prize Competition
18 April 2013
The Competition is open to all aged 33 or under at the end of 2012. Entrants submit an original paper relating to any aspect of tunnelling which they consider of interest to those in the tunnelling industry. The evening consists of presentations of shortlisted papers by the authors, following which, the winner will be announced.

Preston project report
16 May 2013
A report on the construction details of this project in the north of England.

Gotthard Base Tunnel
20 June 2013
A report on the longest transport tunnel in the world will be presented by Rainer Rengshausen of Hochtief.

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