APRIL 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON ASIA

News and reports from Hong Kong and Singapore

MUCK TRANSPORT

T&TI's takes a look at the latest in conveying technology

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HONG KONG: SCARCITY OF SPACE IS THE MOTHER OF INVENTION.

Hong Kong is one of the most populated places in the world and when constructing new infrastructures space is at a premium, even underground. The two tubes of the »Hong Kong Kowloon Southern Link« railway tunnel run parallel at the start, in the middle section they run one on top of the other and at the end they run parallel again. The foundations of Hong Kong's skyline must be passed with small curve radii and at a distance of only a few meters.

On March 12, 2008 the Herrenknecht S-335 Mixshield (Ø 7.99m) reached final breakthrough after excavating 2x 1,100m in 18 months only. Up to 100 meters per week were driven through granite. Another reference project for the use of Mixshield technology »made by Herrenknecht« for geologically demanding inner-urban tunnelling has been successfully completed.

HONG KONG | CHINA

PROJECT DATA	CONTRACTOR
S-335, 1x Mixshield Diameter: 7,990mm Driving power: 2,400kW Tunnel length: 2x 1,100m Geology: weathered and fresh granite	Link 200 Joint Venture, Leighton Contractors (Asia) Limited, Balfour Beatty Group Ltd., Kumagai Gumi Co., Ltd., John Holland Pty. Ltd.

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A Robbins Company conveyor system runs along one of the East Side Access project's Manhattan hard rock tunnels, in the US (p43).

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Risk in it all...

You only have to read Keith Wallis' article on p22 to get pretty excited about the industry's future. The wealth of work described coming up in Hong Kong alone should be enough to cheer even the most pessimistic of engineers. Now before you say, "that's just Hong Kong, so it won't help me," think it through.

Hong Kong is a modern city, and in many ways a template for the type of urban growth we are seeing globally, and will continue to see - burgeoning populations with increasingly restricted surface areas for development.

So it's not too outlandish to believe that this is just the start of things to come, as more cities follow suit and attempt to sort out their infrastructure by looking below ground.

These are exciting times, there's no doubt that as an industry we have the tools and experience to build these huge schemes, but there do seem to be a few issues throwing a spanner in the works – current risk assessment and management processes being one.

It would appear we are, or are being forced to, assess risk in far too prescriptive a fashion, with the worrying knock-on effect that engineers are becoming wary of innovation. No project is, or ever will be completely risk free, simple as that. I also believe engineers don't become engineers not to take on any risk. Nothing would ever have been built if that were the case. Nearly every engineer I know will say that one of the joys of the discipline is the opportunity to innovate, to think outside the box, often on the hoof.

Increasingly, however, this is becoming harder to achieve with willing hands virtually tied behind backs. Put simply, over-prescriptive risk assessment is making innovation too chancy, and in many ways stripping engineering of one of its main draws as a career.

For an engineer who just wants to get on and get building, this can be deeply frustrating. I am in no way advocating taking unnecessary risk - health and safety of the workforce and general public is paramount and a sensible approach to risk assessment is without question a vital part of this process - but surely there is a way of going back to a more basic, direct, approach to tunnel procurement.

Risk is safest in the hands of those best suited to deal with it. And those hands belong to the innovators and tunnel builders. We must ensure that as an industry, we are not head-locked into fearing innovation, as it is sometimes these forward steps in thinking that go a long way to eradicating risk, well, most of it.

Tris Thomas

COMPANIES IN THIS ISSUE

Herrenknecht to make 19m TBM for Moscow

Herrenknecht has been awarded a contract to undertake a feasibility study for, and to deliver, a 19m diameter TBM to excavate a combined road and rail tunnel in Moscow.

ZOA Infrastruktura awarded the contract late last month for the TBM to work in the 'very demanding' soft ground geology and high groundwater levels in Moscow. The customer wants the machine, likely to be a Mixshield, on site in two years.

Infrastruktura is to build the tunnel on the outskirts of Moscow as an orbital transport link that connects into the road and metro networks. Financial details were undisclosed.

The diameter of the proposed TBM far exceeds the biggest shield built so far, also by Herrenknecht. The largest TBMs at present are the two 15.43m diameter Mixshields (S-317, S-318) that are excavating twin tunnels almost 7.2km long below the Yangtze river in Shanghai for the Pudong-Changxing crossing, part of the new link to Chongming.

The first TBM on the project was launched in September 2006 and the second Mixshield began boring in January 2007. The TBMs will drive 65m below ground at their deepest point and are expected to encounter up to 47m head of groundwater above the tunnel axis (*T&TI*, January 2007, p7). The drives are expected to finish later this year, and the entire, almost 7.5km long, tunnel crossing is to be finished in 2010. The contractor is Shanghai Changjiang Tunnel & Bridge Construction Development Co.

Herrenknecht has previously supplied a large diameter Mixshield to help expand the transport network of the Russian capital, on the Lefortovo and Silberwald projects. The 14.2m diameter machine in question had previously been used in the late 1990s to construct the fourth tunnel below the river Elbe in Germany.

Refurbished as S-164, the TBM was sent to Moscow for the Lefortovo project, in which AO Corporation Transstroy built twin 2km long, segmentally lined bores through sand, clay and limestone for double-deck road tunnels, which included excavation below the river Jausa.

After refurbishment, the Mixshield was then used by OAO Mosmetrostroy, as S-250, to excavate twin 1.5km long road tunnels through sand, clay and boulders on the Silberwald project in Moscow. At present, the shield is being refurbished once again for another job in the city where, as S-483, it will drive a single 2.4km bore on a project being undertaken by Upravlenie Mosmetrostroja (UMM).

NFM bags four more China orders

NFM Technologies has received orders totalling approximately US$35M for four EPBMs for the Shenyang and Shenzen metro projects, in China.

The identical 6.28m diameter shields are identical to the TBMs already working on the Guangzhou metro, the company told *T&TI*. NFM will manufacture the main components of the EPBMs at its facilities in Le Creusot, France, with integration and assembly undertaken in China by its partner Shenyang Heavy Machinery Group (SHMG).

New NFM TBMs are identical to those sent to Guangzhou (shown)

Two EPBMs are being supplied to Shenyang Municipal Construction and the China Railway Engineering Co for delivery in December this year and January 2009, respectively, for work on the Shenyang Metro.

The first will drive a 1179m rail tunnel from Century Square and Xiashengou stations. It will be the second machine that does the more excavation, however, by driving two 1123m long tubes below Canal South river to link Quingian Park and Industry Exhibition hall stations. The latter EPBM will have a cover of approximately 10m to the river bed.

NFM has already supplied three TBMs for construction work on Shenyang's metro – two in 2005, and one last year for Line 1.

The manufacturer is also to supply two EPBMs to Shenzen Municipal Engineering Co by the end of this year for the Shenzen metro project. The machines are to drive twin 2300m long tunnels to link An Tuoshan and Xiang Mei North stations via Qiao Xiang and Xiang Mi Lake.

Last year, NFM had orders for seven TBMs in or near Shenzen – two for a rail link and five 6.28m diameter shields for the metro (four for Line 2, one for Line 3).

NFM is majority-owned by China's Northern heavy Industries (NHI) group, which also holds SHMG. The Chinese company took 70% control as part of a financial rescue plan for the company last year. NFM is still protected by the French commercial court, and that will expire in mid-2010 upon completion of the firm's debt settlement plan.

Tunnel boring started a few months ago in Tabriz, Iran, with the machines that triggered NFM's financial problems when the client severely delayed payments. The TBMs had been kept in storage until payments were received, in 2006, but by then the knock-on effect had caused severe difficulties and the protection of the commercial court was sought.

The company became very active in China with SHMG prior to the takeover, and NFM continues to be busy in the country. It said 15 TBMs were sold in China in 18 months. Excavation is underway with the first of four slurry shields in Shiziyang, it is to supply two TBMs to the Yintao water diversion project, and work is nearly complete with its TBMs on the Wuhan twin bores (*T&TI*, February, p7).

Malmö hole through

The first of the twin EPBMs boring the rail tunnels for Malmö's Citytunnel project holed through last month to complete its drive at the central station – earlier than originally scheduled, and the second could breakthrough before the end of this month.

Slightly more than 4.6km was excavated by the 8.89m diameter Herrenknecht TBM named "Anna" over almost 500 days, said Bilfinger Berger, which is part of the Malmö Citytunnel Group (MCG) consortium building the project under a US$325M (2001 prices) design and build contract. Other members of the JV are Per Aarsleff and E Phil & Sons.

Final breakthrough of the first TBM on the twin rail tube drives in Malmö

The TBM started excavating, in Holma, in late November 2006 and in late August last year it holed through at the intermediate, Triangeln station to complete the first, 2.7km long drive. At the station, the TBM was pulled through and overhauled before being relaunched in mid-November to bore the final, 1.9km long stretch to Malmö Central – Malmö C.

Anna's sister machine, "Katrin", kept pace in the range of 500m-600m behind and followed a similar sequence at Triangeln (*T&TI*, October 2007, p6). The contractor said that when Anna finished her drive the second machine had approximately 500m to go and was due to breakthrough in about a month, in late April.

Driving through limestone geology at depths of 20m-25m and with groundwater almost 20m above the tunnel invert, it was expected that the drives from Triangeln to Malmö C would present the more difficult tunnelling conditions, including more residential areas and a number of tighter turns. It was noted by the client at the time of the relaunch that following the experience of the first drive the public would be able to detect vibrations as structure-borne sound, for a few days, as the TBM grinded its way below their immediate area.

Previously, the client had said that the tunnel drives were expected to be completed by mid-year or the third quarter, and the anticipated hole through by Katrin would mean excavation was executed a few months faster than planned.

The running tunnels are being excavated some 10m-30m apart along the route, and the TBMs have been installing 350mm thick concrete segments (7+1) to form 1.8m long rings of 7.9m i.d.

The Client, Sweden's National Rail Administration (Banverket) wants the entire project, which has a budget of US$1.3bn (2001 prices) to be completed by 2011. The project will connect Malmö's central rail system with the Øresund bridge to Copenhagen, Denmark, and also tie into the Scania network.

Lovat takes steps ahead

Lovat – which has just been acquired by Caterpillar (see p13) – has won a further contract for a hard rock TBM from Russian contractor Bamtonnelstroy and seen a refurbished EPBM get underway with excavation on a sewer project in Istanbul.

Bamtonnelstroy has ordered a 4.24m diameter single shield TBM to drive a 2,253m long drainage tunnel for the Krolsky project in Russia. The machine is to be fitted with 17" disc cutters. Excavation is to start late this year.

Geology along the alignment comprises limestone, schists and dolomites with UCS up to 150MPa. Tectonic zones are expected in the schist, and some short stretches of soft, mixed ground are anticipated. Groundwater levels vary from 3m-20m above invert.

Lovat previously supplied a 9.5m diameter machine to the contractor to excavate a rail tunnel on the project.

In Istanbul, the refurbished 3.45m diameter mixed face EPBM on the first, 5,227m long Gurpinar section of the Tahtakale-Ambarh sewer had advanced more than 450m by late last month. Best daily production by contractor Oztas so far is 16m and the machine (RME136SE Series 19501) is advancing at an average rate of 14m.

Geology comprises hard to stiff over-consolidated plastic clay containing some weak sandstone, siltstone, claystone and tuff. Groundwater levels result in heads up to 60m. Depth of cover varies from 6m-132m. The second section of sewer on the project is the 3,770m long Firuzkoy drive (*T&TI*, July 2007, p10).

CVA blames ground for collapse at Pinheiros

Point load stress on SCL lining, caused by an undetected rock mass in soft soil after heavy rains, has been identified as the likely cause of last year's fatal collapse of the Pinheiros shaft and station cavern in São Paulo by an independent consultant's report for the JV contractor.

The Odebrecht-led JV, Consórcio Via Amarela (CVA), gave a local public briefing on the findings in the report that was presented to the client and the authorities, including the state government's Institute of Technological research (IPT). The investigation and report were by consultant Nick Barton.

While it was reported that a response to the report was anticipated by IPT, a spokesman for the Institute told *T&TI* that it was completing its own, official, investigation. It is expected to be published in the near future.

The sudden collapse happened on 12 January 2007 and seven people died. But it wasn't until two months ago that investigators were able to examine collapsed parts of the cavern's structural support immediately above the original floor level.

The most extensive evidence of failure was of major 'punch loading' of the heavy, 850mm spaced lattice arches of the 18m span, 40m-long cavern. The SCL had a minimum of 350mm thickness of steel-fibre reinforced shotcrete. Last year, *T&TI* reported that tunnel crown collapse was seen as a possible failure mechanism (*T&TI*, January 2007, p5). Near the base of the excavations the engineers also found evidence of over-loading of the supports and footing failure at the bedrock.

It was judged that key contributory factors to the collapse were a local combination of a smooth geological discontinuity plus a broken, over-capacity flowing sewer causing a local softening of soil. Their unfortunate affect was to loosen the hold on an undetected, adversely-shaped standing ridge of foliated rock directly over the excavated cavern.

The report concludes that where more detailed site investigation is costly and physically difficult in congested urban environments then, possibly, deeper metro construction might be advocated, such as done for cities that lack suitable geology. It adds that rock conditions are generally more favourable at depth due to weathering in tropical regions, such as in Brazil.

... while TBM makes good progress

Boring resumed last month with the 9.46m diameter EPBM on the running tunnels of São Paulo metro's Line 4 when it was re-launched from Oscar Freire following a lengthy stop due to works at the station.

The Seli crew driving the shield rapidly got back to achieving the best daily advance rates of 19 rings (28.5m), which has been achieved a few times. Average daily progress in the sandy clay has been 10 rings (15m). Tunnel lining is segmental (7+1) concrete of 8.43 i.d., each ring being 350mm thick and 1.5m long.

So far on the single bore tunnelling project, the best weekly advance has been 90 rings (135m) achieved last September on the drive from Fradique Coutinho to Oscar Freire, which it reached in November 2007.

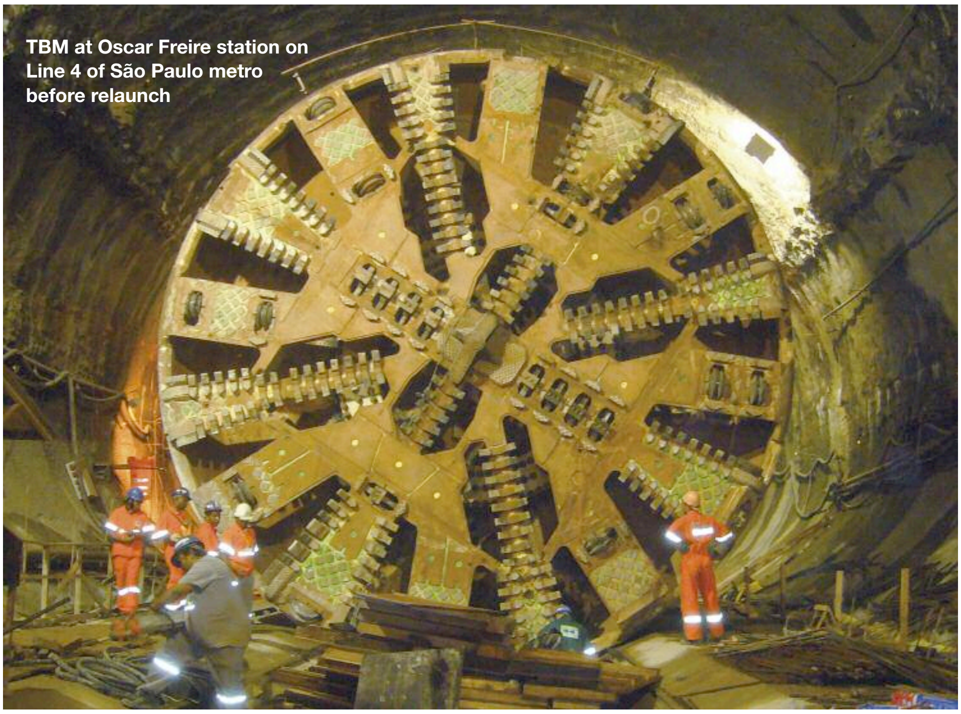
The Herrenknecht TBM is due to reach the next station, Paulista, by early June. At the station the shield will be dragged through to drive to further stations on the new metro line – Higienópolis-Mackenzie, República and Luz. The shield has less than 4km to bore before terminating at the ventilation shaft at Joao Teodoro, near Luz station, around the middle of next year.

The hole through at Fradique Coutinho was the first for the TBM, which was launched on the 6.4km long tunnel from a box at Faria Lima in February last year. The shield is excavating much of the eastern stretch of the metro line (*T&TI*, August 2007, p8).

Seli is undertaking the TBM drive on behalf of the Odebrecht-led joint venture contractor Consórcio Via Amarela (CVA). It received the order almost three years ago as a contract package of US$410M (2005 prices).

Geology along the alignment comprises Tertiary silts and sands along with gneiss of the São Paulo and Resende basins.

The World Bank has approved a US$95M loan to São Paulo for the Line 4 expansion project. The loan has a term of 25 years following a five-year grace period.



TBM at Oscar Freire station on Line 4 of São Paulo metro before relaunch

Brenner set to start

Boring on the exploratory tunnel for Austro-Italian Brenner rail link starts this month

Excavation of the exploratory tube with a 6.3m diameter Seli TBM for the Brenner Base Tunnel project below the Austro-Italian border is to be officially inaugurated at the end of this month.

The 20 month drive for the 10.5km long, first section of the exploratory tube that will eventually run the entire length of the 55km long main tunnels, is being undertaken by a joint venture contractor, ATB Consortium Tunnel Brenner.

The JV, which was awarded the €78.9M (US$124M), excl VAT, contract in the middle of last year, includes: Pizzarotti, Bilfinger Berger, Alpine Mayreder, Beton –und Monierbau, Jaeger, Seli, Collini Impresa Costruzioni, and Societa Italiana per Condotte d'Acqua.

Starting on the Italian side of the project, the works begin at Aicha where the double shield TBM will drive through Brixner granite with some faults and groundwater expected in defined areas. About half the drive is expected to be rock Class III, and 40% as Class II. Most of the first section of tunnel (9.5km) is to be lined with shotcrete and rock bolts, and the remainder will have segmental lining.

Other excavations for the section of tunnel include a 1.79km long adit, by drill and blast from Mauls. At the end of the adit there will be a 200m-300m long cavern opened up by NATM, and which will be used to receive and dismantle the TBM. Separately, a 400m long tunnel is to be excavated to remove spoil to the Riggertal deposit.

The contract, to be completed by 2010, is the first of four planned by the client, Brenner Basis Tunnel SE, to build the exploratory tunnel. The unified, single tube will later be used as the service tunnel between, and below, the main tunnels.

Tunnelling on the opposite, Austrian end, will start with a 5.6km long NATM excavation from Innsbruck to Ahrental, where a 2.4km long access tunnel will be built. The other section in Austria will see a 3.1km long adit at Wolf that then enables drives of 7.5km and 5.2km in opposite directions – the latter towards Italy. Coming towards it will be a 13.1km bore launched from a 3.9km long adit.

Overburden of up to 1,600m is anticipated for the stretches of tunnel works below the border, and an 8km long zone in the area is where the African and European tectonic plates meet to form the Alps. The main running tunnels to be bored through the area will have an excavated diameter of 9.6m.

NZ mulls Humboldt rail tunnel

New Zealand's Department of Conservation is mulling a proposal by Milford Sound Link Rail (MSRL) for a 13.5km long tunnel under the Humboldt Mountains in the Fiordland National Park on the South Island.

MSRL has applied for a land use concession to build and operate the single bore, single-track rail tunnel, which would run from Routeburn to Hollyford Valley. The tunnel is part of a larger transport scheme that would shorten the distance between Queenstown and Milford Sound by 60% from 304km to 121km.

The company hopes that work on the tunnel could start in 2012 or 2013 to get the rail link operational by 2015. Trains operating in the tunnel would haul roll-on/roll-off carriages for buses, cars and other vehicles.

Routeburn portal would be on private land and even though the Hollyford portal would be built on Crown land, at Gunns Camp in the national park, MSRL believes the challenge of getting approvals was not insurmountable.

No details of the cost of the tunnel have been released, although a proposal for a shorter, 10.2km long, bus tunnel was estimated to cost NZ$150M (US$119M). If the rail tunnel is approved then the plan for a bus tunnel, put forward by the Milford Dart Company, would either have to be scrapped or amended because a previous plan was stopped when the Department of Conservation refused to change the area's management plan.

Dibco takes TunnelTec for Calgary

TunnelTec has supplied the 2.46m diameter cutterhead and tools for Canadian contractor Dibco Underground's TBM drives on the 15th Street Sanitary Sewer Siphon Upgrade project in Calgary, Alberta (*T&TNA*, March, p22).

Varied ground conditions called for the cutterhead and tools on the American Auger TBM to be re-configurable for rock or soft strata, or to operate in combination mode, during the two 300m long drives below the Bow river. The second tunnel will be excavated over the first in the US$14M contract.

TunnelTec, through its US representative American Commercial Inc (ACI), is supplying 12" front-loading disc cutters, scrapers and rippers with bolted connections as requested by Dibco to ease change in excavation mode. The tunnel lining will be ribs and lagging, and a 1.5m diameter pipelines will be installed and backfilled in place.

Dibco felt the existing soft ground cutterhead on the TBM would not be adequate for the ground conditions as presented in the bid documents. The order for the cutterhead and tools was placed in January.

India sees Robbins on AMR...

The first of two 10m diameter Robbins double shield TBMs was launched last month to begin excavation of a 43.5km water tunnel for the Alimineti Madhava Reddy (AMR) scheme in Andhra Pradesh state, India.

Robbins said the second machine would be assembled later this year at the opposite portal to drive towards the first TBM. Factory pre-assembly is not being employed for the machines. The TBMs are being assembled only onsite, in launch pits along with the back-up system and continuous conveyor assemblies.

Contractor Jaiprakash's project manager, Anil Khamat, said the assembly work for the first TBM went "quite smoothly" though he said there were "some minor mismatch problems that were worked out". Robbins commented that onsite assembly saves time for the contractor and money.

Geology along the route comprises half in quartzite zones (up to 450MPa) that are layered and separated by shale, and the other approximately 50% in granite (160MPa-190MPa). Both machines will be fitted with back-loading 20" cutters, and the drive motors are to operate at higher than normal revs/min to optimise penetration rates in the hard rock section.

Following the drives, the TBMs and back-ups are to be removed via a dismantling chamber excavated by drill and blast.

The first of two Robbins TBMs for India's AMR water tunnel was launched last month

Jaiprakash is building the tunnel for the state government to convey water from Srisailam reservoir for irrigation and other water resources in Nalgonda District by the end of 2012. The entire construction period for the project is about 60 months.

Robbins is also to supply a 10m double shield for another long drive on a different water transfer project that will tap the same reservoir – the Pula Subbaiah Veligonda project, also being developed by the state government. Onsite assembly only is also planned for the TBM and back-up, and excavation is due to start in February 2009. Excavation of a smaller, parallel tunnel has already started on the project by a Herrenknecht machine (*T&TI*, February, p8).

...and MTR at Delhi metro

Hong Kong's MTR Corp has been awarded an engineering and project management contract with the preferred concessionaire on the Delhi Metro airport link.

The transport company's international railway consultancy unit was appointed to the Airport Metro Express Line (AMEL) project by preferred concessionaire for the scheme, a JV of Reliance Energy and Spain's CAF. MTR Corp beat four rivals with its US$16.4M bid.

MTR Corp is to define all electrical and mechanical systems for the project and ensure that all procurement, installation and testing and commissioning works are carried out.

The 22.7km long AMEL link is scheduled to be completed in July 2010, just before the Commonwealth Games in New Delhi. Supervision of the construction work will be undertaken by the city's transportation client, Delhi Metro Rail Corp (DMRC).

Almost 70% of the link will be built in tunnel, but only 3.8km long twin bores are to be excavated by TBM after August for completion in 2009. A total of four TBMs are to be employed - two by the JV of Alpine, Hindustan Construction Co (HCC) and Samsung on the twin 2.3km drives of the AMEL-C1 section, and two more on the twin 1.5km long drives on the AMEL-C5 stretch being built by the JV of Shanghai Urban Construction (Group) Corp and Larsen & Toubro (L&T).

TBMs for other parts of the expanding Delhi metro network are already in the ground to excavate other lines (*T&TI*, March, p8).

Reliance Energy is part of the Reliance-Anil Dhirubhai Ambani Group, which is one of the largest conglomerates in India. The 30-year concession will see Reliance Energy operate and maintain the line.

MTR Corp said its experience in Hong Kong of planning, designing, building, operating and maintaining a dedicated airport express rail link was a key aspect of it succeeding in the bid competition.

Cat expands into TBMs with Lovat buy

Canadian tunnel boring machine manufacturer Lovat was bought last month by Caterpillar, which paves the way for the international plant group to expand into the competitive tunnel boring machine sector.

Neither the cost of the acquisition nor financial terms of the deal were disclosed. Contact leading to the deal started some months ago and entered 'a more detailed and serious phase within the last few months' prior to the announcement, at the end of March. The deal has been closed.

Lovat will become part of Caterpillar's Global Mining Division, but the brand name is to remain the same 'for the foreseeable future'.

Head of Lovat, Rick Lovat, will join the division and has responsibility for driving Caterpillar's ambitions in the tunnelling sector. The parties said Caterpillar was pleased to have him and his team in place to provide continued guidance and leadership for the new business for the group.

While giving the plant group an in-road to the tunnelling sector, the acquisition affords the Lovat TBM business the benefits of Caterpillar's purchasing power, R&D initiatives and funds, global footprint and experience in large-scale manufacturing processes. They added that the combination 'should result in positive growth' for the business, particularly due to the portfolio fit and the 'long-term demand for major infrastructure projects around the world,' though expectations were not quantified.

However, they declined to outline the strategy to develop the TBM business, except that the primary TBM manufacturing facility will remain at Lovat's site in Toronto, continued employment has been offered to all Lovat employees and no job losses are anticipated as a consequence of the acquisition. Caterpillar HR staff have met with Lovat workers to begin the transition process.

The parties told *T&TI*: 'From a business and operations standpoint, we are also working to determine best practices from Lovat and Caterpillar in order to find quick wins that will benefit this business and our TBM customers.'

Caterpillar intends to leverage its global business with continued investment in the Lovat product line and in the tunnel boring business, they said. But, with respect to possible other purchases, they commented: 'Caterpillar is focused on profitable growth, but is unable to speculate on future acquisition plans.'

Rick Lovat (right) has sold Lovat Inc, to Caterpillar in a move that brings the plant group into the TBM market

Vinci, Eiffage JV wins Marseille job

A joint venture of Vinci and Eiffage has been awarded the concession to build and operate the Prado Sud toll tunnel in Marseille.

The Vinci-led JV is to invest a total of US$303M in the 46 year concession contract, which includes US$230M for studies and construction. The value of construction work undertaken by Vinci and Eiffage will be according to their stakes in the JV – 58.5% and 41.5%, respectively.

Under the concession, the JV will finance, design, build, maintain and operate the 1.5km long tunnel, which is an extension of the 2.45km long Prado Carenage tunnel which was built in the early 1990s.

The double-decked road tunnel will have two lanes on each level with width restrictions and vehicular height limit of 3.2m.

Vinci and Eiffage are also partners in the concession for the neighbouring Prado Carenage tunnel. They plan is to use the same toll firm to operate the new tunnel when it comes into service, scheduled for 2013.

The contract was awarded by the municipal authority and the concession holder is the special purpose vehicle, the Prado Sud company.

TfL takes Metronet

Metronet is about to be taken over by London's transport authority, TfL, which will also get the failed subway concessionaire out of Administration.

The Mayor of London approved plans to transfer the business and its assets and staff to TfL, which hopes the arrangements will be completed soon, possibly in May.

The two Metronet businesses – Metronet Rail BCV ("BCV") and Metronet Rail SSL ("SSL") – went into Administration in July 2007, having unsuccessfully sought extra payments from the client. BCV had called for the public-private partnership (PPP) contract referee, the PPP Arbiter, to judge the issue (*T&TI*, December 2007, p12).

TfL needed to ensure the fulfilment of the upgrade programme and late last year emerged as the sole bidder for the Metronet package. Shortly before, a number of senior executives left the Metronet firms and new management was appointed by the PPP Administrator, Ernst & Young.

The setbacks for the Metronet firms have hit the financial performance of the JV companies behind the ventures – Atkins, Balfour Beatty, EDF Energy, Thames Water and Bombardier. TfL said the recent agreement of Bombardier and Westinghouse to continue their work on the Victoria line upgrade was a 'significant' step towards getting Metronet out of Administration.

Eurotunnel sees profit

Eurotunnel has improved its financial performance to edge into a pro-forma, first time profit of US$2M for 2007 on its underlying business, but the improvement in net earnings was much more after financial restructuring benefits.

Earnings before interest, taxes, depreciation and amortisation (EBITDA) was 12% higher at almost US$880M, on revenues 6% higher at US$1.55bn.

The trading profit jumped 22% to US$554M but, after the exceptional profit of US$6.64bn due to the restructuring, the net earnings were effectively equivalent to that huge saving. Debt servicing was cut down by 40% by the financial restructuring.

The company said that the improved performance was aided by further income from Eurostar passenger trains following the full opening of the high-speed rail link (HS-1) to London, although that was late in the year. Eurostar passenger volumes increased 5% to 8.26M.

In addition, Eurotunnel also benefited from increased traffic levels for its core business of car and freight shuttles between Folkestone and Calais, which saw revenues lift 8% to US$1bn. Vehicle traffic was 8% up to 1.4M lorries and 2.14M cars.

In the first quarter of this year the increase in traffic was proving to be sustained, Eurotunnel added.

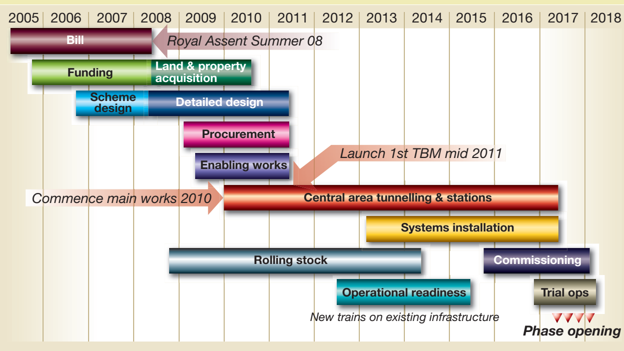
Crossrail puts out pre-qualification call

Calls for expressions of interest were issued in early April to companies looking to provide overall programme and project delivery partner services, and also those seeking to operate as design consultants, for the Crossrail project in London.

The delivery partners will help the client manage detailed design and implementation phases of the project. The deadline for submissions to be a delivery partner is noon, 16 May, and it is planned that the shortlisted firms will be invited in June/July to tender, and the appointments are due before year-end.

Cross London Rail Links (CLRL), the development company for Crossrail, said it wants feedback from prospective delivery partners to refine the outline Delivery Strategy. The programme delivery partner will manage the project delivery team, and it is not excluded that a single bidder could hold the role at each level. The project delivery partner will be responsible for the central tunnel section, excluding the Heathrow spur.

Firms seeking to operate within the design consultant framework for the project have until noon, 12 May, to submit expressions of interest. The development phase of the project, which will result in a single option design solution for most locations for the consultants to take forward, is to be completed mid-year.



The Crossrail team said that the number of TBMs required for the project remains at seven for the US$33bn project (*T&TI*, November 2007, p7). Main construction work is still planned for 2010, tunnel boring is to commence mid-2011 and train services are due to commence 2017. In total, 41.5km of 6m i.d. rail tunnel is to be bored. Tunnelling works for stations in central London are to be excavated using SCL with steel fibre reinforcement for primary and secondary linings.

The Bill to give legal authority to execute the project has almost completed the third of six stages in the House of Lords, and Royal Assent is expected mid-year. The third stage is the Select Committee hearings. Last year, the Bill was passed by the House of Commons.

CLRL is jointly owned by the state and London's transport authority, TfL. It has utility diversion works underway in central London but will not be able to take possession of land or property until the Bill receives Royal Assent. At that point, TfL will become sole shareholder of CLRL, which is a private company. Also, CLRL will not decide on the award of contracts until after the Bill is approved.

A notice was also issued early April for enabling works in advance of the contract notice that is to be issued later this year.

U Mole bought by Vp

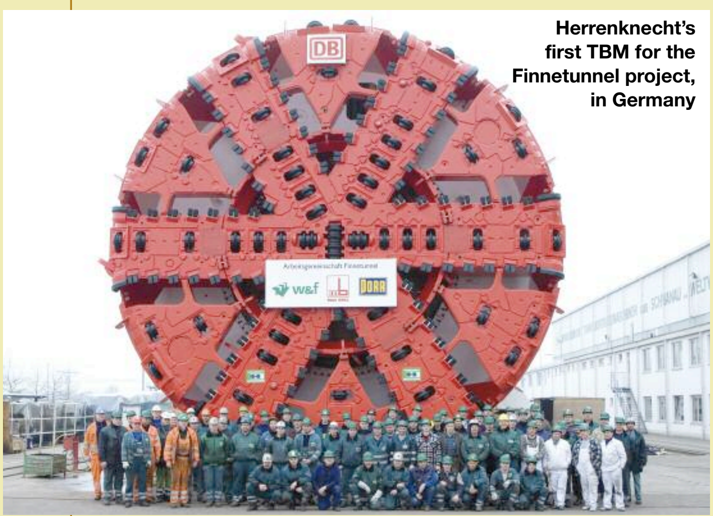
England-based trenchless equipment supplier U Mole has been acquired through UK group Vp's purchase of its parent, UM (Holdings) Ltd.

The specialist equipment rental group said it bought UM (Holdings) Ltd for almost US$2.8M. U Mole is to keep its brand name and operate in Vp's Groundforce division.

Vp said the addition of UM (Holdings) Ltd would add to its offering to the regulated utilities market. Earlier this year, U Mole was made sole European representative for US TBM manufacturer Robbins' small boring units.

Herrenknecht '07 sales - orders up

Herrenknecht, the German TBM manufacturer, has reported sales revenues up an impressive 30% to US$1335M for the year 2007, and orders were 48% higher at just over US$1.6bn for the period.


Herrenknecht's first TBM for the Finnetunnel project, in Germany

The latest performance continues the trend of increasing revenues and order levels, and the number of trainees has also risen to 121 which exceeds the previous peak, in 2004. Staff numbers are now at 2345.

The increases last year by the TBM and tunnelling equipment systems group exceeded those enjoyed in 2006, of 27% higher revenues at US$853M, (2006 currencies) than in 2005. Orders then improved 39% to US$930M (2006 currencies). Trainee numbers in that year were 101, down to the lowest since 2003.

With orders high, including more recently a feasibility study for a 19m diameter machine (see page 6), Herrenknecht has machines excavating a number of projects – including Cabrera, Sao Paulo, Malmo, Veligonda and Gotthard, with a number of others being manufactured or in transport to site, such as for Rome, Delhi, Jinping II and Finnetunnel.

Excavation at the Finnetunnel rail project is expected to start next month with the first of two 10.82m diameter Mixshields for the JV contractor to drive twin 6,825m long bores. The TBM, S-419, had workshop acceptance in late January. Workshop acceptance of the second TBM, S-420, is hoped shortly.

Much excavation is set to commence in Rome, Italy, this year for which Herrenknecht will supply a total of six machines. The firm's sole TBM at Cabrera, in Spain, is currently being prepared for a mid-year restart to drive the second of the twin rail tunnels for the high speed link (*T&TI*, March, p11).

Driving Kowloon's Southern Link

David Hake, TBM tunnel manager, for Link 200 JV describes the challenges encountered during the twin, stacked, slurry TBM drives for the Kowloon Southern Link project, in Hong Kong

Kowloon Southern Link contract KDB200 is part of a 3.8km railway project to link the operational East Rail and West Rail lines for client MTR Corporation (formerly Kowloon Canton Railway Corp, prior to a merger in Dec '07), in Hong Kong. The KDB200 Contract includes twin TBM tunnels, West Kowloon Station, two emergency access and egress shafts, northern cut & cover tunnels connecting to an adjacent contract and southern cut and cover tunnels connecting to the existing station at East Tsim Sha Tsui.

The US$259M (HK$2.018bn) KDB200 contract is being carried out under a design and build contract by the Link 200 JV, comprising Leighton Asia, Balfour Beatty, Kumagai Gumi and John Holland. Mott Meinhardt is the designer for the JV.

The Link200 JV bid proposed a slurry TBM for construction of the 1.1km long, twin 7m i.d. tunnels through mixed ground beneath the congested shopping, hotel and tourist area of Tsim Sha Tsui in Kowloon. This is only the second project in Hong Kong to use a Mixshield TBM, the first being the Kai Tak Transfer Scheme (*T&TI*, April 2004), which was also undertaken by John Holland.

Urban area tunnelling constraints

Due to the building density in Tsim Sha Tsui, the available reservation for the alignment was generally beneath public roads, however a tight 225m radius curve was required beneath the heritage listed Former Marine Police Headquarters building.

The width of the road reservation in Canton Road, due to existing basements and piled buildings, meant the tunnels were required to be stacked vertically with just 6.25m of clearance (see p19) in this section.

To achieve the stacked configuration beneath Canton Road the tunnels needed to change elevation to ensure enough clearance between the drives. This meant driving the TBM on up and down grades in the order of 3%, in conjunction with the 225m horizontal radius curve.

These grades were also required to ensure enough clearance to the other alignment constraints, such as passing beneath the Kowloon Park Drive flyover, Kowloon Park Drive Subway No.1 and clear space between the tunnels.

Due to its urban setting, a key consideration for the project was the ability of the TBM to limit settlements and ground borne noise impacts. In addition to the TBM selection, contingency plans were developed for identified risk areas, including:

- Kowloon Park Drive Flyover – contingency deck jacking plan
- Emergency access and emergency egress shafts and connection adits passing –

Below: Fig 1 - Alignment and geology

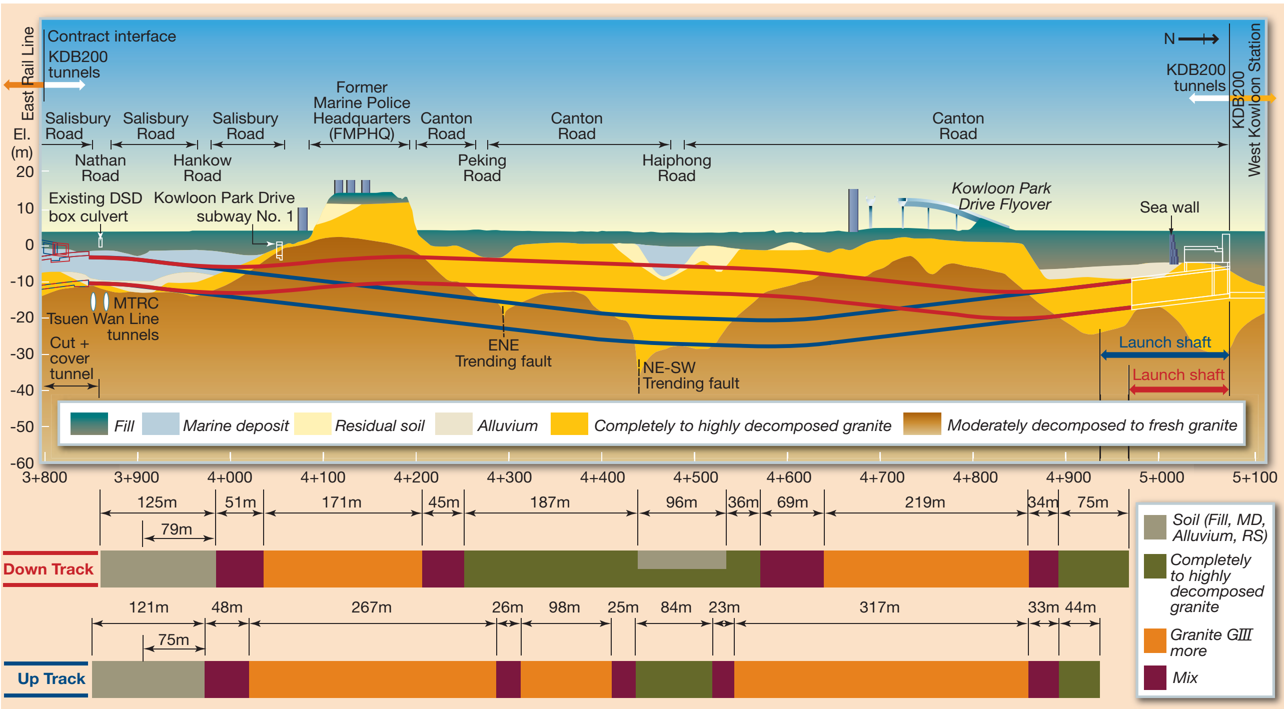


Table 1: Key TBM feature
8.05m excavated diameter
Designed for rock and soft ground
Bi-directional (left and right), 0-5rpm
41 x 17" Herrenknecht single disc cutters
4 x 17" Herrenknecht twin disc centre cutters (+ overcutter), face spacing 100mm
Jaw type rock crusher up to 800mm size
108 soft ground scrapers
2400kW installed for main drive with 14 hydraulic motors
4m diameter main drive
Single articulation to suit 225m radius curve
Open backup to minimise rolling stock grades

Left: The launch shaft in West Kowloon

temporary lining

- Kowloon Park Drive Subway – reduced operating pressure
- MTRC Tsuen Wan Line crossing and DSD culvert passing – ground treatment and isolation horizontal pipe piles
- Emergency temporary traffic management

Ground conditions

The tunnels encountered varying ground conditions, all below the groundwater table (with pressures up to 2.6 bar at axis level) and within close proximity of Hong Kong Harbour. Both tunnels encountered a full range of ground conditions including completely decomposed granite (CDG), mixed face of CDG and fresh granite, full face of granite, faulted zones and mixed face of CDG, alluvium and marine deposits, as identified in the geotechnical investigation report.

Areas of shallow cover included both launches (right to left, as shown in figure 1) within CDG and alluvium, overlain by marine-placed reclamation granular fill; as well as within the marine deposits at Salisbury Road, when side by side at the end of the drive.

The start and end of each of the drives were similar, however beneath Canton Road the tunnels were in the stacked configuration and therefore encountered different conditions. The first drive experienced more rock and increased water pressures at greater depth and the second drive was shallower with more soft and mixed ground (CDG/granite interface, CDG with corestones (fresh to slightly decomposed granite boulders within a completely decomposed granite matrix), alluvium and marine deposit).

TBM selection

The twin tunnels were both about 1100m in length and one TBM was used for both of the tunnel drives. The TBM was planned to excavate the Up Track (lower) tunnel first, then be recovered and relaunched to complete the Down Track (upper) tunnel.

The key TBM selection criteria were:

- Control of face pressure in soft ground, mixed face conditions and shallow cover to minimise surface settlement
- Ground water inflow control at faults and interfaces
- Hard rock production rates
- Excavation through corestones and blocky ground
- Spoil handling systems
- TBM shutdown and maintenance periods
- Wear and abrasivity
- Ground borne noise impacts

A 7.99m diameter Herrenknecht Mixshield TBM was selected by the JV for the project, as it was considered more suitable for maintaining accurate and reliable face control and groundwater control, particularly at the soil/rock interface and corestone zones. The ability to manage wear of the cutterhead and cutters and cope with blocks or boulders, by use of a rock crusher behind the submerged wall, were also considered superior with the Mixshield than for an EPBM, or slurry TBM by another manufacturer.

The TBM was designed in Germany and key components, such as the main drive, cutterhead, motors and pumps, were manufactured in Europe. The steel structure of the TBM and the back-up equipment were manufactured in Shanghai and Guangzhou, China, respectively. The TBM was then assembled and commissioned in Herrenknecht's Guangzhou factory and shipped directly to the job site.

Segmental lining

The tunnel lining design was undertaken by Mott Connell (as part of the Design JV for the project). The lining was required to be 7000mm i.d. to allow for walkways, M&E provisions and kinematic envelope. The 350mm thick reinforced concrete lining was developed for a range of loading conditions including ground, surcharge, handling, TBM operation loads, and TBM thrust loads due to steering through the 225m radius curve in rock.

The concrete mix specified for the segments was a grade 50/10 mix, including a corrosion inhibitor additive for durability and polypropylene fibre for the four hour fire rating required for the lining.

Two ring types were used for the alignment, both universal taper and six segments plus one key:

- A nominally 1500mm long ring for the general tunnel with a taper of ±12mm to achieve a 500m radius curve, and
- A nominally 1200mm ring for use at the 225m radius curve with a taper of ±25mm

The segments were sealed using a Phoenix EPDM rubber gasket with hydrophilic insert. The EPDM gasket was installed at the precast yard and the hydrophilic gasket installed on-site prior to delivery to the TBM. Spear bolts and inserts, by Sofrasar, were used on the radial and circumferential joints. The ring

Right: Finished tunnel lining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build teams were very experienced from previous projects in Hong Kong, and hence the ring build damage was very low.

Tunnel drives

The working site for the tunnel operation is located at the northern extent of the hotel and retail area of Tsim Sha Tsui. Two sides of the site are bound by high-rises, with the other two sides facing an expansive open area and the station construction. The site operated under strict Environmental Protection Department issued construction noise permits (CNP), hence the shaft contained an acoustic enclosure, along with all other surface fixed plant to allow tunnelling operations on a 24 hour basis (such as the MTRC crossing). Prior to completion of the noise attenuation, site activities were constrained until 11pm, after which site noise was required to be less than 55dBA at the noise sensitive receivers.

The TBM drive was launched from a 22m deep diaphragm wall box with approximately 14m of cover. The end wall of the shaft was constructed using fibreglass reinforcement (GRP) in the panels. Outside the diaphragm wall was a zone of jet grouted columns to enable the secondary seal on the launch wall to be installed. The GRP reinforcement caused minor delays due to blockages within the rock crusher grill and also at the STP during the launch. Cleaning to remove the jet grout and GRP from the slurry was carried out, in parallel with grouting of the secondary bullflex launch seal ring, prior to moving into the natural ground.

The tunnels encountered corestones within the CDG over the first 100m of tunnel until the first interface, between the CDG and bedrock, was reached. The tunnels were only 6m apart through this launch zone however the second tunnel experienced more boulders and a less cohesive matrix and this resulted in greater cutter damage. Over a similar length of tunnel at the start, almost four times as many cutters were used during the start of the second drive due to damage. The interventions to repair cutter damage were carried out under compressed air beneath the three lanes of traffic in each direction.

The TBM then encountered hard granite, in the order of 110-185MPa, beneath the Kowloon Park Drive Flyover section. Advance rates of 10-12.5mm per minute were achieved in the Up Track drive compared to a designed rate of 15-20mm per minute. During the second drive, using similar loadings and RPM, the TBM achieved 20-25mm per minute, as the extent of fracturing was greater than encountered in the first drive.

Advance rates in the soft ground, full face CDG or marine deposits, were in the range 40-55mm per minute, governed by the annulus grouting rates and spoil handling at the slurry treatment plant.

The TBM was designed with tail shield grouting using a traditional grout mix and pump system with grout excluder plates on the outside of the tail shield to stop grout travelling forward to the shield. During launch of the TBM in the first drive the grout excluder plates became entrapped in the secondary launch seal. It then became difficult in hard rock to contain the grout within the annulus surrounding the rings and as a result of grout loss in the crown some ring flotation was experienced, mainly after free air

Above: **Alignment of the drives, as seen from the southern East Tsim Sha Tsui Station interface**

interventions in rock for cutter changes. Although the floatation issues were overcome, the grout system was changed late in the first drive to a two-component grouting system, with an on-site batch plant, from Meiwa and this provided greater flexibility for grout supply to the TBM for extended working hours. The product was pumped from the surface batch plant via two 50mm lines for the grout mix and two 25mm lines for the accelerator. The mix was injected through the segments in the shoulders of the rings.

The 225m radius curve in hard rock presented issues for the lining design and TBM steering, however these were overcome by providing additional clearance around the shield, offsetting the outer cutter positions using packer plates. The 5mm-10mm additional over-cut enabled the TBM to negotiate the curve successfully.

The TBM survey was carried out by the JV, utilising a guidance system supplied by VMT with ring selection software.

Cutter changes were undertaken in compressed air for maintenance in mixed ground conditions using the Hong Kong Compressed Air Regulation tables and an emergency medical lock was provided on the site surface during the project. The maximum compressed air pressure used in the lower section of tunnel was 2 bar gauge pressure and a project limit working time of up to 3 hours.

Owing to the adjacent sensitive structures, a number of "no planned intervention zones" were identified. In these zones it was preferred to tunnel without undertaking maintenance on the cutterhead to reduce the risk of slurry or compressed air losses during the intervention. This further risk mitigation/ control was employed prior to commencement of the second drive after an Up Track performance review (*T&TI*, June 2007, p6).

Salisbury Road and MTRC crossing

The final section of both tunnel drives included shallow tunnelling under Salisbury Road in marine deposits, the MTRC Tsuen Wan Line crossing with less than 2m of clearance, and 2m of clearance beneath a DSD culvert (connected to the harbour).

In this zone where cover reduces to less than one diameter and clearance between the tunnels reduced from 3m to under 1m, jet grouting in advance of the drive was employed. The JV installed horizontal pipe piles above the MTRC tunnels to isolate the TBM drive from the existing running tunnels. This isolation was required as the tunnels were built through mixed ground in mid-1970's and were subsequently refurbished by removing the inner face of the rings and reinforcement, replacing these with steel fibre shotcrete.

The 23.5m crossing of the MTRC tunnels on both drives commenced at 10pm on a Saturday evening, in June 07 and March 08. This meant that the passing of the TBM's cutterhead above the crown of the MTRC tunnels occurred outside normal traffic hours.

In addition to the instrumentation in the MTRC tunnels (see Settlement Monitoring), traffic hours train cabin inspections were undertaken and non-traffic hours manual surveys were undertaken. Monitoring within the tunnels was linked to a project control centre, which included the TBM operational data, so that full monitoring could be undertaken.

The TBM drives successfully crossed the MTRC tunnels on both occasions with negligible movement recorded.

Slurry treatment plant

The excavated spoil was transported in a slurry suspension through 350mm diameter pipes to a slurry treatment plant (STP) provided by Pigott Shaft Drilling (PSD), with a 1350m^3 per hour flow capacity. The STP consisted of a primary screening unit, three desander units, two centrifuges with a flocculation system, bentonite mixing system and storage tanks. The primary screen had a steeply declined deck to separate all material greater than gravel size. The three desander units were two-stage, each incorporating a single 660mm hydrocyclone and a bank of 18 x 5" hydrocyclones. The two centrifuges were parallel in the system to separate the fines. A flocculation unit was operated with the centrifuges to remove fine particles and process waste slurry for disposal.

The slurry treatment plant system was sized to suit the maximum advance rate of the TBM based on the grading curves for CDG and marine deposits. However, during the Up Track drive it was determined that delays between excavation cycles could be further reduced by the addition of another centrifuge, to increase the plant's fine particle processing capacity. An additional centrifuge and flocculation system was mobilised for the second drive enhancing performance in the soft ground sections.

The spoil discharged from the STP was transported by conveyor to an adjacent spoil handling area. In the soft ground sections, where 24hr weekend excavation was required, the on-site spoil bin area was extended, as under the CNP trucks were not to be used between 11pm and 7am, Monday to Saturday, or at all on Sundays. From the bin area, spoil was loaded onto trucks and transferred to a barge loading ramp for disposal at both marine dumping and land based filling areas.

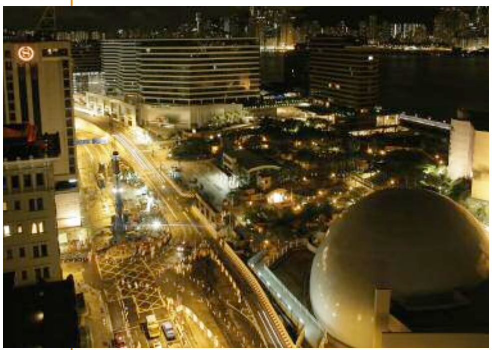
TBM disassembly and recovery

The TBM reception shaft is located at the corner of Salisbury Road and Nathan Road, in Tsim Sha Tsui. The site is bound by three traffic lanes on two sides and a major intersection on the third side. Therefore road closures and diversions were required to mobilise the 500t mobile crane and trailers for the removal process.

The 10 main TBM components were planned for removal over a 14 night period, with an operational window from midnight to 6am. Each night the road closures commenced at midnight, then the crane and counterweight was set up, the lifts completed, load secured to the trailer, transported under police escort to site whilst the crane was demobilised and the road re-opened. The back-up trailers were removed through the tunnel using purpose built bogie cars and removed from the launch shaft over six days.

Due to congestion of utilities at the shaft, there was no direct lifting available for the Up Track recovery. To enable the components to be placed under the crane hook, the shaft floor was plated with steel and the cradle fitted with Teflon plates prior to pushing the TBM into the shaft.

Below: The cutterhead is removed from the reception shaft; final breakthrough



Settlement monitoring and control

An internet based monitoring system was selected for use on the project, providing both SMS and email notifications in the event of exceeding the preset alert, action or alarm (AAA) values. The monitoring system utilised information from over 1300 monitoring points, 300 'real time' and 1000 manually input, including:

- Surface and utility settlement markers
- Vibrating wire piezometers, piezometers and standpipes
- Tilt meters and inclinometers
- Automatic deformation monitoring systems (ADMS)
- CCTV cameras in MTRC tunnels

The tunnelling passed through soft ground and mixed ground conditions at shallow cover along both Canton Road and Salisbury Road and the design face loss for the settlement performance using the Mixshield was estimated per drive as:

- CDG: 0.3% face loss
- Mixed face (soil/rock): 0.5% face loss
- Marine deposit: 0.7% face loss

It was envisaged that settlement measured for the second tunnel, when in the twin stacked tunnels configuration, may produce higher than anticipated levels. The actual settlement measured over a length of 400m beneath Canton Road have been less than the equivalent of 0.1% face loss in CDG, interface alluvium and marine deposits. Some minor heave was recorded along the alignment due to annulus grouting.

In addition to the surface monitoring, in-tunnel monitoring, using prism arrays, was installed in in three specific areas of the completed Up Track tunnel: 1) Tunnels side-by-side in close proximity in CDG; 2) Tunnels stacked vertically in close proximity in CDG; 3) Tunnels side-by-side in close proximity in marine deposit and jet grout. The in-tunnel monitoring did not reveal any significant movement in the first tunnel as a result of the driving of the second tunnel.

Ground borne noise and vibration

The alignment passed numerous noise sensitive receivers (NSRs) including the Hong Kong Cultural Centre (HKCC) facility.

Early GBN monitoring was undertaken to determine the impacts and validate the initial modelling and the levels measured were generally as predicted. The HKCC impact was limited to +3dB increase and the studio theatre levels reached +7dB. For the closer but less sensitive buildings, the impacts were limited to relatively short exposures as the TBM passed.

Completion of drives

The KDB200 TBM tunnels have overcome a range of tunnelling issues. The alignment required steep grades to achieve the twin stacked tunnel configuration and a tight radius curve to achieve the rail track design. The cover was variable between the two drives but was shallow in difficult ground conditions beneath public roads for the majority of the second drive. A number of instances of close proximity TBM passing were required, including adjacent to shafts, existing buildings and above the MTRC Tsuen Wan Line tunnels.

The second tunnel commenced in October 2007 and was completed in early March 2008. The best week achieved was 102m. The TBM has since been removed from the reception shaft, and the back-up through the tunnel, completing a technically challenging project through one of the most congested areas of Kowloon. T&T

Heralding a new era in Hong Kong

With a vast array of tunnelling works about to kick off in Hong Kong, regular *T&TI* contributor, Keith Wallis, takes a look at some of the region's key forthcoming rail, water and road tunnels

Hong Kong is set for a tunnelling boom over the next five to 10 years the likes of which have never been previously seen. As huge investments are made to expand the rail, road and drainage networks, insiders believe the total cost of projects will easily exceed US$15.4bn (HK$120bn), although cost estimates for some of the schemes have not been accurately forecast.

By far the largest amount of money will be spent expanding Hong Kong's rail network. This has been sparked by December's merger of the territory's two rail companies - the MTR Corporation and the Kowloon-Canton Railway Corporation - into a single entity. The merger, which was completed after years of discussions, provided the catalyst for government officials to announce the green light for a series of long-delayed rail projects, including a new cross-harbour rail line.

The government is also investing in new road and drainage tunnels including an ambitious road tunnel under one of Hong Kong's busiest shipping channels.

Some of these schemes have already provided a rich seam of employment for experienced consultants such as Ove Arup & Partners and Maunsell Consultants Asia, with more work still to come. Contractors too will benefit as the projects reach the tender stage.

But the surge in tunnelling work has sparked warnings of staff and labour shortages and soaring costs once projects are underway. "Whenever we've raised the issue with officials the response has been one of only mild interest. There seems to be a feeling that people who left Hong Kong to go to the construction boom first in Macau and then Dubai will want to return to Hong Kong. But we wonder if that is true," said one insider. "They won't if the money and opportunities aren't there," he added.

"Admittedly, tunnelling is not so labour intensive as other construction sectors, but the shortage of skilled employees and cost escalations are very real issues," he said.

The massive investment in the rail network will help stave off the contraction in government-funded public works that has gone on for the past few years. Finance Minister, John Tsang, said infrastructure spending in the 2007-08 financial year was HK$20.5bn, the lowest for several years, and considerably less than the HK$29bn per year predecessor Henry Tang claimed had and would be spent on infrastructure.

Mr Tsang said: "The main reason for the decrease in expenditure is there are not enough infrastructure projects, especially major ones, ready for implementation. I believe that expenditure on infrastructure has bottomed out. It will rise to HK$21.8bn in 2008-09." This does not include the estimated HK$80bn already earmarked for rail projects.

Rail infrastructure

Hong Kong's rail network will be expanded by about 50km if all the planned rail schemes go ahead.

The first to be approved was the HK$8.9bn project to lengthen the existing Island Line on Hong Kong Island (see map on p24). The MTR Corp got the green light to start preliminary planning and design of the 3km West Island Line extension at the end of the November, even before the physical merger with the KCRC took place.

The extension, which will be built entirely underground, will continue the Island Line to Kennedy Town with the help of a HK$6bn capital grant from the government. Three new stations will be built at Sai Ying Pun, the University of Hong Kong and at Kennedy Town. Construction will start in 2009 for completion by 2014.

The rail corporation said current plans envisage a TBM will be used to excavate the twin running tunnels between Sheung Wan and Sai Ying Pun. The section between Sai Ying Pun and Kennedy Town station would be built using cut-and-cover techniques with extensive blasting through rock.

The extensive use of explosives will require the construction of a temporary underground magazine to store explosives for blasting. Given the hilly nature of the area, a large network of underground walkways will also be built to optimise public access to the stations.

Final government approval to move ahead with construction is expected to be given by early next year ready for construction to start the same year.

Hard on the heels of the West Island Line extension was approval for the HK$7bn eastern section of the South Island Line, a north-south railway running through the centre of Hong Kong Island (see map).

MTR Corp has already awarded a

preliminary design contract to Maunsell Consultants Asia. The nine month assignment, which is due for completion by the end of this year, will look at the scope of the project, risks, construction methods, estimated costs and transport planning.

The 7km line will have the capacity to handle 20,000 passengers per hour in each direction, compared with the usual capacity of 85,000 travellers per hour for the rest of the MTR network. The railway will run from the existing Admiralty station, southwards to South Horizons on Ap Lei Chau island.

New stations will be built at South Horizons, Lei Tung, Wong Chuk Hang and Ocean Park on the south side of Hong Kong Island, along with a depot near Wong Chuk Hang station. Talks are also underway about the possibility of building a new station at Wan Chai and Happy Valley.

The line will connect with the existing Tsuen Wan, Island and future Sha Tin to Central lines via an interchange at Admiralty station. The MTR Corp said: "A significant portion of the line will be in tunnel with the remainder elevated." About 4km of the line is expected to be built in tunnel.

The main tunnel section will run from Admiralty through Hong Kong Island's hill range to close to Aberdeen. A second tunnel section will be excavated on Ap Lei Chau. Only the station at Lei Tung on Ap Lei Chau will be built underground, while South Horizons station will be built partially underground. Transport and housing minister Eva Cheng Yu-wah said the aim was to complete the line by 2015.

The railway forms the eastern section of the South Island Line. Ms Cheng said the western section would be built later on, depending on the development of the area. The western segment is planned to run from the end of the Island Line extension at Kennedy Town, via Wah Fu, Cyberport and Aberdeen, to Ocean Park where it would connect with the eastern line.

But the biggest underground rail project to get the green light so far is the HK$41.6bn Sha Tin to Central Link and associated Kwun Tong Line extension, which won preliminary approval from the government in mid-March.

The government gave KCRC the rights to develop the Sha Tin-Central railway six years ago, in a move that was bitterly and angrily opposed by MTR Corp. KCRC awarded seven major scheme design contracts, including preliminary plans for a fourth harbour rail tunnel, for what was an 18km long railway linking Sha Tin in Hong Kong's New Territories with the central business district.

But further progress was stymied after it became clear there were moves afoot for MTR Corp and KCRC to merge.

Under the government's March initiative, MTR Corp has been told to go-ahead with preliminary planning and design of the 17km HK$37.4bn Sha Tin to Central Link and the 3km HK$4.2bn Kwun Tong Line extension to Whampoa. Both lines are expected to be built underground.

MTR Corporation chief executive C K Chow said: "The Sha Tin to Central Link and the Kwun Tong Line extension will mark an important milestone for railway services in Hong Kong. These two railway lines, with a combined length of 20km, will benefit not only the residents in the areas along the alignments, they will also add to our existing network providing more convenient rail services to the people of Hong Kong."

The Sha Tin to Central line has been spilt into two, with the first section running 11km from Tai Wai to Hung Hom, while the second section will run 6km from Hung Hom station to new stations at Exhibition, in Wan Chai, and Admiralty. The Tai Wai-Hung Hom segment will have stations at Diamond Hill, Kai Tak, To Kwa Wan, Ma Tau Wai and Ho Man Tin. It will connect to the existing West Rail line at Hung Hom station and there will be a new train depot at Diamond Hill. Construction of the Tai Wai-Hung Hom section is expected to start in 2010 for completion in 2015, while the Hung Hom-Admiralty section is expected to be complete in 2019.

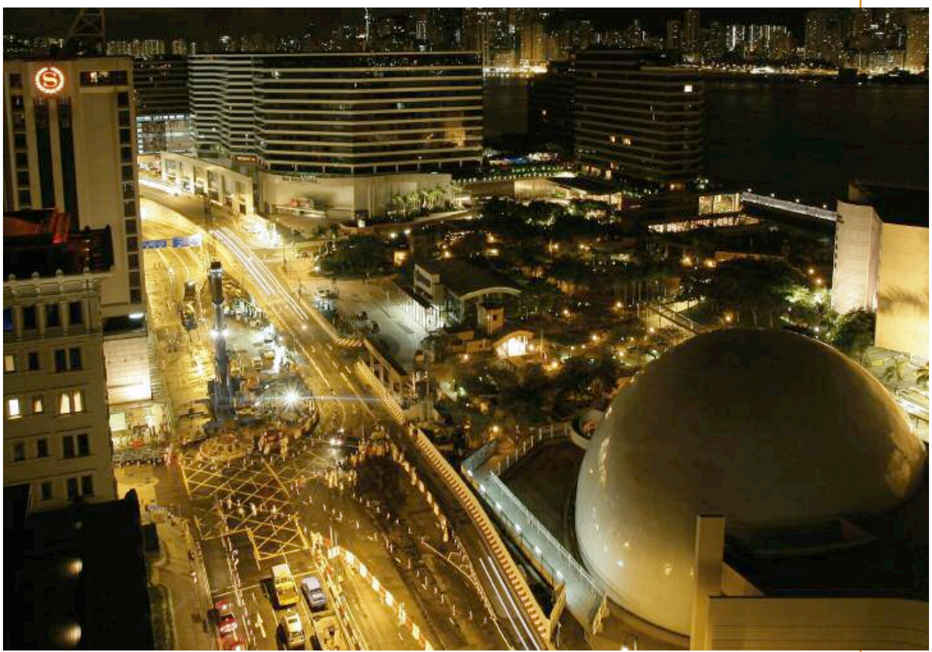
Construction is also expected to start around 2010 on the Kwun Tong Line extension, which will run from the existing Yau Ma Tei station, via the new Ho Man Tin station, to Whampoa. The extension, which will connect with the Sha Tin-Central line at Ho Man Tin, is expected to be complete in 2015. The government has agreed to underwrite HK$2.2bn in funding support for the extension, which is likely to come from the rail corporation being given the rights to develop nearby property.

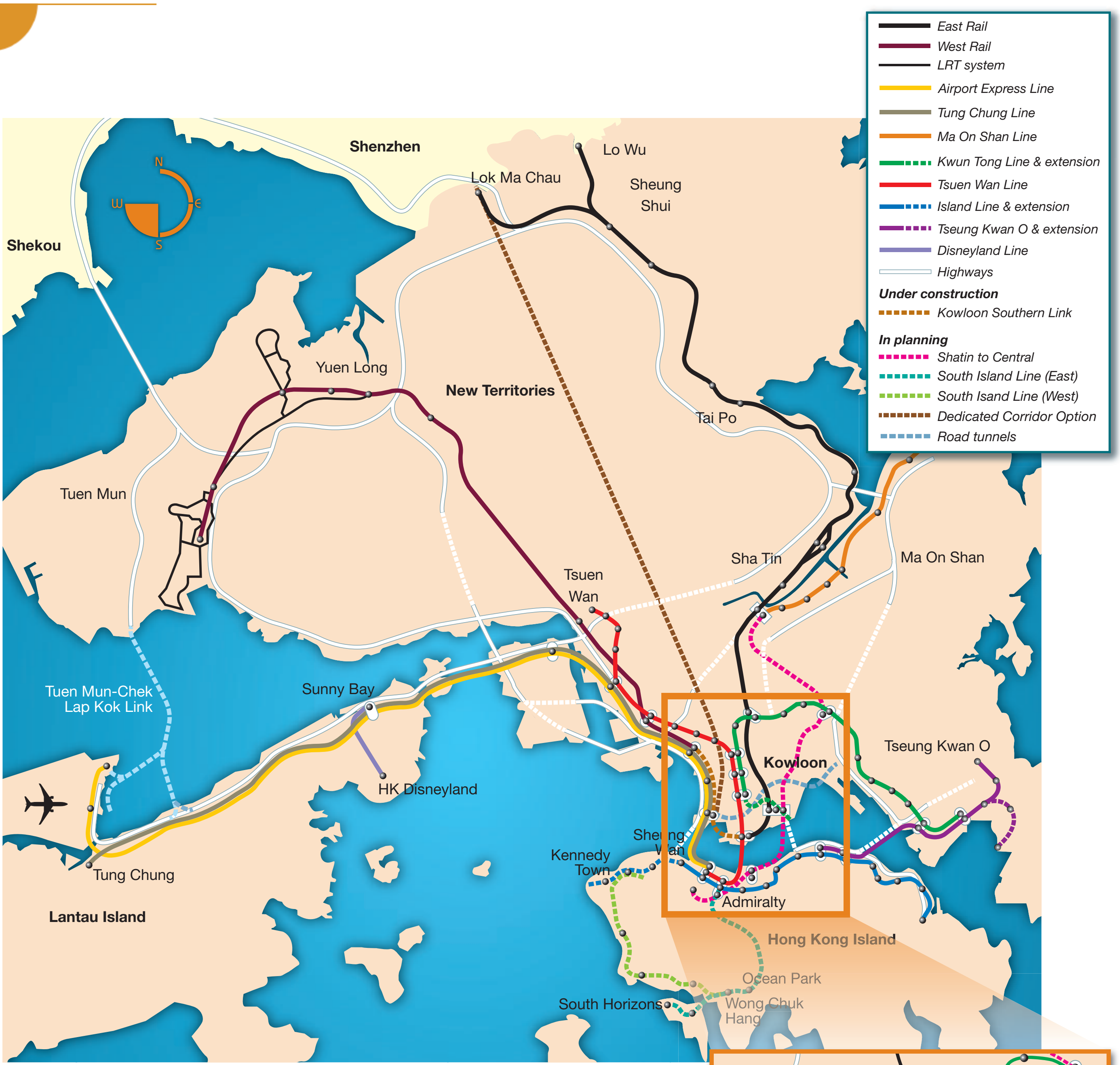
Ambitious, long-term plans have also been drawn up for two further rail projects that will require extensive tunnelling. The first is the 30km Hong Kong section of an express railway linking Hong Kong, Shenzhen and Guangzhou in southern China. About 26km of the Hong Kong section will be in tunnel. Lloyd's Register Asia has just been appointed by the Highways Department (the department has responsibility for rail projects at a government level) to carry out a review of the institutional arrangements for using a franchise to build and operate the Hong Kong section of the railway. If, as seems likely, the concession approach is used then MTR Corp will be among, if not the only, contenders.

No concrete details of the project have so far been revealed, although it is envisaged the tunnel section will comprise a twin bore. However, insiders suggested the tunnel could be similar to the 5.5km Tai Lam tunnel built by Nishimatsu in joint venture with Dragages Hong Kong on the West Rail line. Nishimatsu-Dragages excavated a single tunnel and built an internal wall to create two separate tunnels.

The express rail tunnel is expected to be operational at least by 2020 when 10 Chinese cities will operate long-haul trains to Hong Kong, generating 15 long-haul return trains per day.

Below: The Kowloon Southern Link (p16) is one of MTRC's current projects





Above: The Hong Kong tunnelling boom includes various rail and road projects

Plans are also being investigated for a dedicated rail line between Hong Kong and Shenzhen international airports that would require a crossing of one of Hong Kong's busiest shipping channels.

Drainage works

Several contractors have already kicked off Hong Kong's tunnelling boom after winning the first of what promises to be a package of drainage and sewerage tunnels. The Drainage Services Department awarded two tunnelling contracts in January totalling nearly US$497M (HK$3.9bn).

The larger, worth HK$2.75bn, was awarded to Dragages Hong Kong in JV with Nishimatsu for the design and construction of the 11km Hong Kong west drainage tunnel. The price was above the government estimate of HK$2.4bn, which insiders said reflected the complexity of the project and material price increases, which had already kicked in since the estimates were prepared.

The tunnel, running between Tai Hang to Pokfulam on Hong Kong Island, will vary in diameter between 6.25m and 7.25m. The contract includes the construction of drop shafts, 8km of adits to connect the drop-shafts with the main tunnel, intake structures and slope stabilisation works associated with the intake structures. The tunnel is due to be finished in November 2011.

The second contract, worth HK$1.12bn, was awarded to Japan's Maeda Corporation in joint venture with Seli of Italy and China Railway Engineering for the construction of the 5.1km Tsuen Wan drainage tunnel in Kowloon. The tunnel will have an internal diameter of 6.5m. Work also includes 80m of adits, three intake structures plus an outfall at Yau Kom Tau. Work is to be completed in 2011.

The department is also assessing bids

from three groups for the construction of a third drainage tunnel. The HK$1bn Lai Chi Kok transfer tunnel comprises a 2.8km, 3m diameter bore from the Kowloon Byewash reservoir to the lower Shing Ming reservoir together with intake and outfall structures. The three prequalified contractors bidding for the job are Leighton with John Holland; Nishimatsu with Dragages Hong Kong and China Harbour Engineering with Shanghai Tunnel Engineering and Alpine Meyreder.

The department is also actively encouraging interest in its next major tunnelling project, the second phase of sewage tunnels as part of the Harbour Area Treatment Scheme (HATS), formerly known as the Strategic Sewage Disposal Scheme (SSDS). The tunnels will be built under the northern and western shore of Hong Kong Island, from North Point and Ap Lei Chau, before heading under Victoria Harbour to the existing Stonecutters Island STW.

A contractors' forum was held in February under the auspices of engineering JV, Metcalf & Eddy-Maunsell, to explain details of the project ahead of the formal invitation of design-construct tenders towards the end of this year.

Plans call for the construction of about 19km of tunnels at an estimated cost of about HK$8bn at depths of up to 160m below sea level using drill & blast through mainly granitic and volcanic rock. The department plans to award two contracts for the tunnels, which will have a maximum i.d. of 3m. There will be 15 vertical shafts. Work is to be completed in around 2013-14.

Highway projects

The Highways Department is also set to extend the territory's road tunnel network with three projects that are in various stages of planning. One of the most ambitious is a HK$20bn expressway from Hong Kong International Airport to Tuen Mun in the north-west New Territories (see map) and the associated Tuen Mun western bypass. The so-called Tuen Mun-Chek Lap Kok link features a 4km long immersed tube tunnel under Urmston Road, the main shipping channel between Hong Kong and ports on the western side of Shenzhen, in mainland China. A further 5.8km of tunnel will be built as part of the Tuen Mun western bypass.

Engineering consultants are in the process of being appointed to carry out investigation and preliminary design of both projects. Construction is due to start in 2011 for completion by 2016.

The department is also continuing to work on plans for the HK$12.5bn, 4.7km Central Kowloon Route, which has now been expanded to a 3.8km long dual three-lane tunnel under the Kowloon peninsular.

An engineering JV formed between Mott Connell, Meinhardt and Hyder is carrying out investigation and preliminary design of the highway, which will feature three different tunnelling methods. A bored tunnel will be excavated for much of the route between West Kowloon and the Kowloon ferry pier. A small section of immersed tube will be laid in Kowloon Bay to continue the highway from the pier to the runway at Kai Tak airport. Cut and cover techniques will be used to complete the highway under the airport. Construction is expected to start around 2010 for completion by 2016.

Meanwhile, plans for a major road tunnel, the Central-Wan Chai bypass, along the northern shore of Hong Kong Island have been thrown into disarray amid continued wrangling over land reclamation. The Highways Department had hoped to start construction on the HK$20.5bn scheme next year. But this target may have been derailed after a harbour protection group won a court victory in March, when it was found the government's plan to carry out temporary reclamation for the construction of the 5km immersed tube tunnel was illegal. The government has now been forced to review its plans. T&T

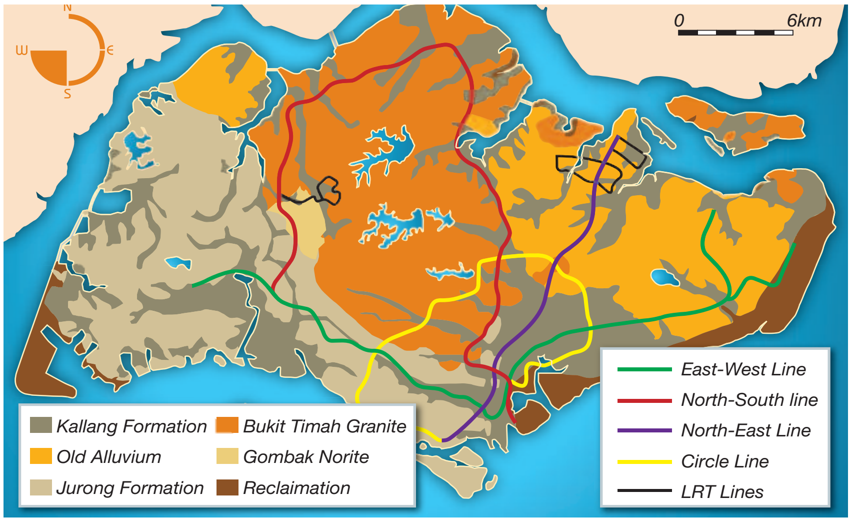
Risk mitigation for slurry TBMs

J N Shirlaw and T W Hulme of Singapore's LTA describe experiences of slurry TBM tunnelling in the Lion State and some of the lessons that have been learned for future projects

Like other technologies, those in underground construction have been developing at a rapid pace over the last 30 years. Each new development helps to solve old problems, but also introduces new risks. It takes time to learn how best to use the new technology. Procedures, organisations and systems that were adequate previously may need to be significantly changed.

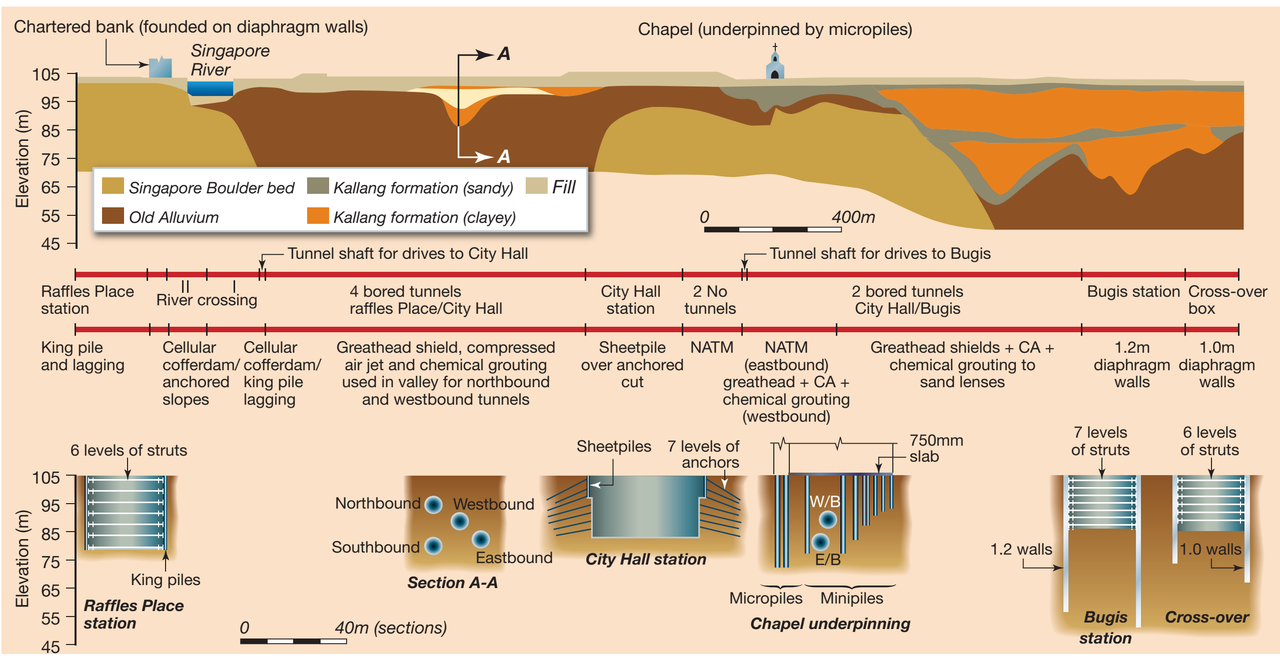
The limitations of the new technology, and any unintended side effects, have to be established and considered in the planning and implementation of the work. There is, in effect, a learning curve that the industry needs to go through as each new technology is introduced. The more rapidly the technology changes, the more learning curves have to be negotiated; with attendant risks while the technology becomes established.

The first phases of the Singapore Mass Rapid Transit (MRT) system, starting in 1983, comprised 83km (figure 1) including 22km of twin tube tunnel divided almost equally between bored and cut and cover methods. The majority of the tunnelling was carried out using open face shields and compressed air. Earth Pressure Balance (EPB) shields were used on just one section of the East-West



Above: **Fig 1 – The 2007 MRT system superimposed on Singapore's complex geology**

Below: **Fig 2 – Geology and methods between Raffles Place and Bugis Station**



line. For the North East Line though, starting in 1997, over 90% of the tunnelling was by EPB shields. Although ground control was generally good, with low settlements, there were some problems of large localised ground loss, particularly when tunnelling in a mixed face of rock and soil resulting from weathering of the Bukit Timah granite.

Slurry application in Singapore

The use of slurry machines, where the face pressure can be maintained irrespective of the rate of advance of the shield, seemed to offer a means of eliminating the face control problems experienced in weathered rock with EPB machines. Much of the MRT Circle Line (figure 1) had to be constructed through variably weathered rock, often directly below buildings, so face control and avoidance of ground loss was a critical issue.

Risk Assessments for EPB or slurry shield tunnelling in Singapore have typically considered the risk of face instability to be negligible, provided a pressurised face machine and an experienced tunnel crew were provided. This has not proven to be the case in practice, and there have been a number of incidents of localised loss of ground. One factor has been the variation in ground conditions, which change frequently and rapidly in Singapore. In one instance, in the first phases of MRT construction, the tunnels from Raffles Place station to Bugis station, a length of less than 1.5km, encountered five distinct changes of strata. In this case, three different tunnel drive segments allowed the equipment to be suitably varied to cope with the changing conditions (figure 2).

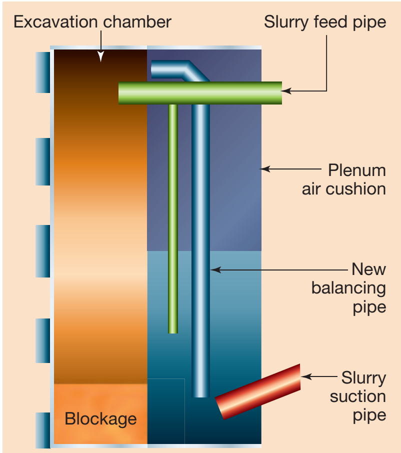
With the use of (more expensive) pressured face machines, longer tunnel drives have been planned. However, longer drives lead to greater variation in ground conditions. The machines have not always performed equally efficiently throughout the different conditions encountered.

There is therefore a need to review the geotechnical and topographic data available, recognise its reliability, or otherwise, assess the machinery obtainable and the work force available and evaluate the risks that may arise. Finally, but as important, is the need to ensure that contingency plans are prepared for all of these eventualities, to allow speedy implementation if and when required.

To illustrate the difficulty of identifying all of the risks introduced by a new technology, a number of the modifications that proved necessary on one slurry TBM drive, are given below. These are examples only, a total of 16 modifications have been required in all.

Some slurry experience

On one section of the construction of the Circle Line the opportunity arose for twin drives of 2.6km each. Over this length it was necessary to select TBMs that would operate satisfactorily in the recent deposits of the Kallang Formation and in the weathered rocks of the sedimentary Jurong Formation and the igneous Bukit Timah granite. Tunnelling conditions in these strata are discussed in Shirlaw (2002). Generally, the tunnels were expected to lie in the Jurong formation, overlain in parts by the Kallang deposits, in the first 60% of the drive. The Bukit Timah Granite would then predominate for the remainder of the drives. To cope safely with these varied conditions, the use of slurry type TBMs was specified by the client, and the Contractor supplied two Herrenknecht slurry type TBMs. It was of course recognised that these TBMs would not work consistently in all of the conditions anticipated. However, it was felt that the use of slurry TBMs would reduce the risk of sinkholes and other disruptions previously suffered by the EPBMs, particularly in the Bukit Timah granite.



Above: **Slurry escape to the surface**
Right: **Fig 3 – The balancing pipes**

Cutting chamber pressure spikes

Almost from the start of tunnelling it became evident that some beds of the moderately and highly weathered rock of the Jurong Formation were breaking down, with excavation, into a sticky clay. There was a tendency for the clay, derived from the breakdown of weathered mudstone of the Jurong Formation, to clog up the suction entry gate area in the invert of the cutting chamber. Even with the addition of a dispersant such as Condat TFA 6 the blockages could not be entirely eliminated.

In the Herrenknecht slurry TBM, the face pressure is controlled by an air bubble in the plenum chamber, with the pressure governed by the Samson equipment. The equipment is sufficiently sensitive to control pressure fluctuations, generally to within +/- 0.2 bars (20kPa). However when the clay created a blockage at the suction entry gate, there was no connection between the excavation and plenum chambers, so the Samson device was no longer controlling the pressure in the excavation chamber. The feed line delivered fresh slurry at 4 to 5 bars and at a rate of 1000m^3/hour.

With the route to the suction line blocked the pressure in the excavation chamber inevitably increased very rapidly. Spikes in the pressure in the excavation chamber occurred suddenly, before the TBM operator had time to react by putting the slurry circuit into bypass mode.

For large diameter (>8m diameter) slurry TBMs it is common for the TBM supplier to provide twin pressure balancing pipes. These pipes provide an alternative means for the slurry to pass from the excavation to the plenum chamber, bypassing the blockage and ensuring that the pressure in the two chambers is equal. In smaller diameter machines the pressure balancing pipes are not normally installed, due to space constraints. This was the case for the TBMs delivered for this project. The tendency of the weathered rock of the Jurong Formation, when broken down by mechanical excavation, to clog was not recognised as a risk in the early hazard analyses.

The more severe of the sudden spikes in face pressure led to loss of slurry to the surface. Where this occurred under or near a

Below and right: The balancing pipes in the TBM – for flushing provision

road the resulting conditions were a risk to road users. To control this risk, two balancing pipes were installed in the first TBM, by retrofitting the machine underground (figure 3). The congestion this caused in the head was obvious and seriously interfered with maintenance. Two pipes were installed, to minimise the possibility of the pipes both becoming blocked. Despite the provision of a water flush to these balancing pipes, blockages did occasionally occur. However, overall, the pressure balancing pipes greatly reduced the number of pressure spikes.

For the second TBM, a second line of defence was instituted in the form of a 50mm pipe from the excavation chamber to a relief valve which would, when it opened under a predetermined excess pressure level, bleed slurry into the invert of the tunnel. This would both relieve the pressure and give a quick visible warning to the TBM operator. With this in place it became possible, to install only one balancing pipe in the second TBM, and preserve access to the other equipment in the plenum chamber, most notably the rock crusher.

With these modifications in place the tunnelling continued more consistently and with significantly less disruption than previously. However the provision of these measures in tunnels under construction was obviously a much greater challenge than had they been incorporated during the original manufacture.

Blockages

Even with the provision of balancing pipes to avoid the pressure spikes when a blockage occurred, the problem of clearing the blockage remained. The traditional method of running the slurry circuit in bypass, and attempting to remove the obstruction by suction only was not always effective. Turning the head without advancing the tunnel, to agitate the slurry, carried with it the risk of over excavation and sinkholes.

Below: A sinkhole above one of Singapores's deep sewer tunnels

To improve the agitation of the slurry and break-up blockages, it was decided to extend the agitator paddles into the suction zone, and double their number from two to four. Two of the slurry supply nozzles were also extended down towards the invert to provide jets of slurry into the area where blockages were of greatest concern.

These jets of fresh slurry agitated and diluted the material in the suction gate area, and helped maintain the excavated material in suspension, aiding the flow into the suction pipe.

Operating parameters

At least as important as the hardware is the need to have all the operating parameters accurately defined and detailed procedures prepared so that all employees are aware of their responsibilities and the actions to be taken in case of unforeseen circumstances.

In compressed air tunnelling, with open face shields, the face pressure was typically adjusted on the instructions of the shift engineer or the leading miner, based on observations of the visible water in the face. This observational approach was not effective where there were sudden changes in ground conditions, requiring sudden changes in the compressed air pressure. A number of spectacular losses of ground, often inundating the tunnel, have occurred due to the failure to adjust air pressures in advance of such interfaces.

Initially, it was common for contractors using pressurised shield machines to use a similarly devolved approach to assessing face pressures, with the shield operator making the decision as to how to adjust the pressure. This approach has not worked in Singapore's rapidly varying ground conditions. Shirlaw[1] records a number of sinkholes that occurred due to failing to plan face pressures to allow for known interfaces.

As recorded in Shirlaw and Boone[2], there were 16 incidents of very large settlement or sinkholes during the EPB tunnelling for the construction of the North East Line, and at least 21 incidents during the construction of the deep sewer system in Singapore. In order to help reduce the number of such incidents, it has been found that it is necessary to:

a) Calculate target face pressure values for every few rings of the tunnel, before starting tunnelling
b) Have enough borehole and piezometric information along the tunnel alignment to have a reasonable basis for the ground and ground water conditions used in the analysis
c) Define levels of authority for changing the face pressure from that calculated, based on observations in the tunnel; in particular the shield operator should not be authorised to drop below the target pressure without confirmation from the tunnel manager
d) Carry out rigorous checking of the net material excavated, either continuously or every few hundred millimetres of advance, to guard against over excavation

Implementing these measures will help to minimise the risk of a local loss of ground.

Where groundwater levels are close to the ground surface, as is the case in Singapore, there is a very small margin between the face pressure required to support the face and the pressure that will expel slurry or foam (for EPBs) to the surface up an open path. It has been found that such open paths are reasonably frequent in urban areas.

The most likely routes are the boreholes and instrumentation installed for the project. However old boreholes, instrumentation, wells and areas where temporary works has been extracted can also be present. There have been cases in Singapore of the loss of up to 100m^3 of slurry to the surface, and in urban areas this can cause almost as much of a problem as a major loss of ground. Open paths should be grouted in advance of tunnelling, where they have been identified.

However, in urban areas it is unlikely that all such paths can be identified prior to tunnelling. It is therefore necessary to:

- Carry out the face pressure calculations as accurately as possible, and without unnecessary conservatism
- Minimise the pressure fluctuations during tunnelling

The measures discussed above are essential to reduce the risk of a major loss of ground or loss of slurry/foam to the surface. Even with the implementation of such measures, in the highly heterogeneous soils of Singapore there remains a residual risk of loss of ground or loss of slurry/foam, and contingency measures for such losses still need to be planned for.

It has been found advantageous, in particularly sensitive areas, for someone to be posted on the surface, above the tunnel,

to identify any signs of a loss of ground or slurry/foam. Simple measures, such as warning signs for a loss of ground or bunds, for loss of slurry, can then be implemented immediately.

Regular look ahead

The need for calculated target pressures for pressurised TBM tunnelling has been identified. It is important that such calculations are not just a paper exercise; the results of the calculations need to be communicated to all of the key personnel in the tunnel, including the shield operators and shift engineers. In addition to the target face pressures they need to be aware of anticipated changes in the geology, and what is above the tunnel. A convenient way to communicate this information is to produce a weekly 'look-ahead' sheet. On this sheet are summarised, for every few rings:

- The anticipated ground conditions
- The target face pressure
- Buildings, roads, railway tracks and utilities above the tunnel
- Any geological hazards, such as faults
- Other hazards, such as sudden changes in ground level due to retaining walls
- Borehole and deep subsurface instrumentation locations

The 'look ahead' is prepared weekly, with about twice the expected week's production covered on a single sheet of paper. The sheet is intended to be a simple means of communication of key aspects of the planned tunnelling to those actually carrying out the work.

Conclusions

The Code of Practice for tunnelling rightly requires risk assessments to be carried out prior to tunnelling. However, it has been found in Singapore that it is common for contractors to list, simply, an appropriate machine from a major manufacturer and an experienced tunnelling team as adequate risk control measures for pressurised tunnelling in an urban environment through highly varied ground conditions.

A number of actual problems, and implemented solutions for slurry shield (primarily) and EPB tunnelling in Singapore have been outlined above. The purpose of giving these examples is to show that trouble free tunnelling is unlikely to happen even with an experienced crew and a specially selected new machine. The problems, and solutions, are also documented as an aid in the identification of risks and solutions on other tunnelling projects.

Preferably the selection of the TBM should be removed from the competitive tendering process. If not, suppliers will always be pressurised to supply a basic machine whereas it is essential that the experienced manufacturer should be encouraged to incorporate the lessons learnt from its earlier machines.

The Contractor must be encouraged to carry out a risk assessment such that the wide experience available in the industry is utilised to make the exercise as comprehensive as possible.

Since no risk assessment can ever claim to have identified every possible hazard then comprehensive contingency plans must be in place and practiced so they can be rapidly implemented if the need arises. T&T

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THE CHANGING FACE OF TUNNELING
2008

SCL challenge under AYA

LTA's project manager, Blaise Pearce, and senior project engineer, Daniel Koh Choon Teck, WSA JV tunnel manager, Massimo Marotta, and Amberg & TTI Engineering designer, Marcus Tong, discuss challenges posed during the construction of a 70m long SCL tunnel in Singapore

The Land Transport Authority (LTA) of Singapore is responsible for the implementation of the Mass Rapid Transit (MRT) System on the island. The rail network is currently being expanded with the Circle Line (CCL) Project, which when complete will add 29 underground stations and 34km to the existing rail transit network.

Circle Line Contract C855 comprises four stations and 5.2km of tunnels, mostly constructed by cut & cover or bored tunnel. However, for a 70m tunnel section under a road called Ayer Rajah Avenue (AYA), connecting a cut & cover box and a station, there are major utilities along the road corridor above the tunnel route that cannot not be diverted. It was decided to construct these AYA Tunnels using the Sprayed Concrete Lining (SCL) method.

The twin tunnels are part of the Contract 855, awarded to JV contractor WSA, formed by Singaporean company Woh Hup, Austria's Alpine Mayreder, and Chinese company STEC. The consultant appointed by the JV for the design of the SCL temporary works is Amberg & TTI, part of the Swiss-based Amberg Group.

The 70m long tunnels were divided into nine construction stages (figure 1). The widths of the tunnels are 11.6m for inner tunnel module 1, 10m width for inner tunnel module 2 and about 9m for the remaining modules.

The selection of SCL was a direct result of the need to minimise ground movements and the risk of settlement damage to the major utilities above the tunnels.

One peculiarity of the AYA tunnels is the narrow pillar of soil between the two tunnels ranging from 1m to 4m accompanied by a shallow overburden in relation to the tunnel diameter (a cover of approximately 1 diameter for inner tunnel module 1).

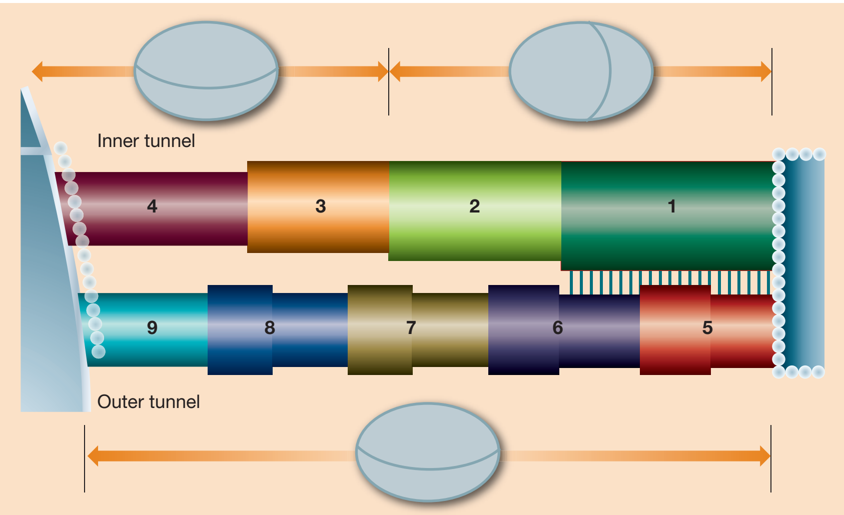
Geological conditions

The AYA tunnel is situated in Tengah Facies of the Jurong Formation, belonging to Upper Triassic to Early Jurassic (100M to 200M years ago) consisting of muddy marine sandstone with occasional grit beds and conglomerate.

A fill layer between 0.7m and 7m thick overlies the Jurong formation. The presence of this backfill was confirmed in most of the boreholes.

The sedimentary rocks of the Jurong Formation, consisting of shale, siltstone, sandstone and limestone of various weathering grades are encountered beneath the fill layer. The rocks are also found to be frequently interbedded.

Below: Fig 1 - Construction Modules for the 70m long twin tube AYA Tunnels



Shotcrete lining

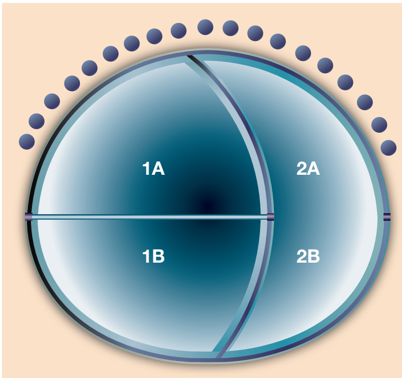
Generally, tunnel supports consist of a shotcrete shell 300mm thick with a double layer of T8-100 mesh, with lattice girders every 1m. A pipe arch consisting of a series of 114mm diameter pipes was installed prior to the excavation of the top heading. Horizontal H beams were designed to be installed across the footing of Stage 1A to provide a lateral restraint to excavation.

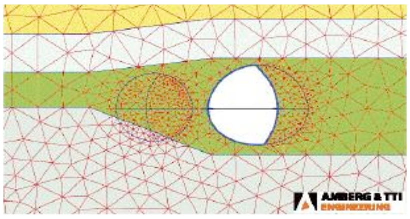
For the first module in the inner tunnel, the excavation face is 92m^2 with a maximum horizontal span of some 21m. Based on the designer's experience in similar ground conditions, the tunnel face was divided into four stages, 1A, 1B, 2A and 2B (figure 2) using the side wall drift method to provide better control over ground deformation. In excavation stage 1A, "elephant's feet" are provided at the invert on each side of the excavation to reduce the tunnel settlement. H-beams were proposed spanning the width of the 1A excavation to provide lateral restraint against the active lateral pressure.

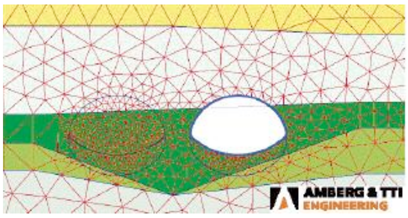
In the design, finite element analysis was performed to simulate the sequential construction of the tunnels and the soil-structure interaction between the ground and the SCL lining. The envelope of the forces acting on the tunnels in all construction stages was used to compute the required thickness of the shotcrete lining wall. The constitutive model for the various soil types is based on the elastic – perfectly plastic Mohr-Coulomb failure criteria.

In the computation, a relaxation factor of 10% was considered in assessing the ground deformation during the excavation stage. This 10% factor has accounted for the presence of the pipe arch roof, which provides a pre-confining effect to stabilise the soil at the crown prior to excavation, as well as the type of soil material that was

Below: Fig 2 – Partitioned face for initial excavation through module 1







Above left: **Finite element model of 1A/1B excavation (side drift approach)**
Above right: **Finite element model of the top heading excavation (TBI approach)**

expected to be excavated. The shotcrete lining and elephant footings were simulated as beam elements. The horizontal beam spanning between the 1A and 1B face was modelled as a node-to-node anchor. Based on the geometry of the section especially the joints at the crown and invert (in 1A and 1B), high bending moments were expected due to the drastic change in curvature. Due to the high bending moment, plastification and cracking of the shotcrete lining would likely occur. To simulate the behaviour of this plastification, a limiting moment capacity was modelled at the joint (a partial plastic hinge) to allow for a re-distribution of the moment from the joint to the shotcrete lining wall. This was critical in carrying out the design adopting the side drift approach. The final closure of the ring, by removing the side drift and excavating 2A/2B in a staggered fashion, resulted in a more stable, rounded geometry and the forces in the lining were mostly hoop stress with a small magnitude of bending moments and shear forces.

Finite Element Model for the TBI

For the typical module in the inner (module 3 & 4) and outer tunnels (module 5 to 9), the excavation face is about 55m^2 to 70m^2 spanning a maximum width of about 10m. As the geometry is relatively smaller both in size and width, the excavation face is broken into just three stages, top heading, temporary invert followed by bench and invert excavation. The temporary invert is necessary due to the presence of residual soil with low SPT N-values (figure 3).

Similar to the side drift approach, the shotcrete lining was simulated in the finite element program as a beam element which includes the elephant footings on both sides of the excavation. A relaxation factor of 10% was again considered in the analysis during the excavation to assess deformation.

As the profile of the excavation generally consists of gentle curvatures, except near the footings of the temporary invert, the bending moments and shear forces were quite small. The predominant force was the hoop force acting within the tunnel lining. The footings were modelled as a series of beam elements of varying thickness to form the transition from the normal section to the enlarged section near the invert. The beam with the larger stiffness naturally attracted higher forces and the lining thickness for the transition was designed accordingly.

In the design for the face stability, a circular tunnel with equivalent diameter and a sliding wedge in front of the tunnel face were assumed. Vertical loading adopting Terzaghi's silo theory was applied on the top of the sliding wedge. The driving force was derived from the overburden soil weight and weight of the wedge. Resisting forces are contributed by frictional and by shear developed both at the inclined slip surface and side areas. GRP anchors (12m) were used at the face to increase resisting forces.

Construction

Presently the Inner Bound tunnel has been completed and permanent lining works are ongoing, while 13m of the Outer Bound has been completed.

The construction of the Inner Bound tunnel started on December 2006, but the construction was almost immediately interrupted by a ban on sand importation from Indonesia to Singapore. After a few heading excavations of 1A, the shotcrete strength was found to be low and did not achieve the required 12hr strength.

Investigations were carried out that found the sand quality to be the primary cause. The quality of available sand from other sources after the Indonesian ban was irregular and mainly too coarse, which resulted in a lower strength shotcrete. During this period, extensive analysis and trials were carried out with the available sand to achieve the required shotcrete strength but was still found to be inconsistent. The situation was only cleared up at the beginning of March 2007 when alternative sources of quality sand became available in Singapore.

The first Tunnel Section to be excavated (A1) was the largest of the entire tunnel. Due to the vicinity of the Outer Bound tunnel, a typical conical shape for the pipe arch umbrella would have further reduced the soil pillar width. For this reason the Section A1 was designed with a constant geometry, taking advantages of the dimension reduction in the next section to have the clearance for executing the next umbrella.

The first challenge for construction was the execution of the pipe arch umbrella that, for a 21m section A1, had to be a minimum of 27m long with a minimum overlap of 6m to the next pipe arch umbrella. In order to verify the alignment of the pipe arch, a survey was executed after each pipe installation, measuring each pipe deflection. Based on this execution/monitoring process, continuous adjustments were done to the drilling methodology in order to achieve the desired result. Grouting was executed with double packer.

The results on the pipe roof alignment were better than expected (considering that the execution was undertaken with a normal two boom jumbo), as summarised in Table 1.

The spacing of 300mm was therefore achieved for most of the pipes. This was critical as it was designed as support for the overburden over the excavation length.

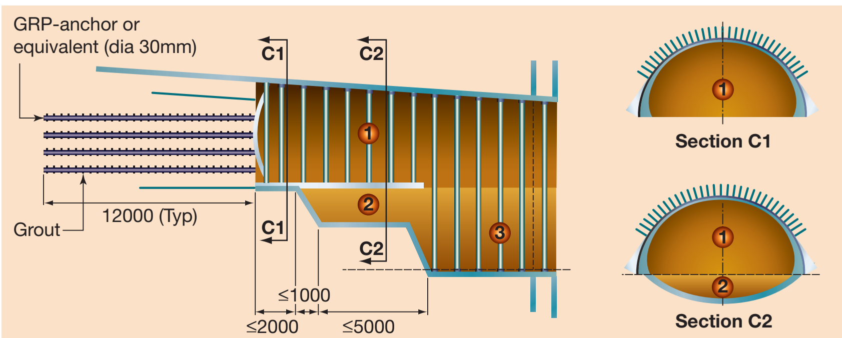
Another challenge has been the construction of the joint between the temporary drift and the final section profile (between 1A/2A and between 1B/2B).

The joint is heavily reinforced due to the high bending moments created during the side drift stage, and due to the need to install lapping bars to assure continuation of the reinforcement within the final profile, creating difficulties for a good application of shotcrete and also the potential for shadows.

In order to assure high quality work, a mock up of the joint was used for training the shotcrete applicators and a second one was used to verify the shotcreting quality.

The construction using the side drift

Below: **Fig 3 – Sequence of the top heading, bench and invert approach**



Left and Above: **Improved accessibility of machinery made possible by the A-frame installation**

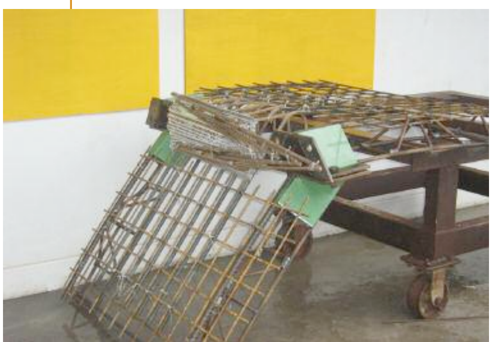
created some difficulties in term of machinery accessibility, especially in the section 1B where mining had to been done below the horizontal H beams.

For the excavation of the first drift 1B, accessibility was further restricted by the pre-constructed permanent base slab for the cut & cover tunnel, causing a restriction in the headroom between the slab level and the installed horizontal H beams. The problem was resolved by replacing the H beam with an "A" frame to increase the headroom for machinery access by around 1m.

During the excavation of the inner tunnel module 2, accessibility for excavation for 1B was also found to be difficult due to the horizontal H-beam constraints. An alternative sequence has been adopted - excavation of the side drift (1A), followed by enlargement (2A), followed by a close excavation of the bench and invert to achieve a faster ring closure. The problem of head room was eliminated as the H-beam could be progressively removed and excavation can be done at the bench and invert.

During the 1st 3m of excavation of the bench and invert, the bench and invert faces experienced localised face instability below the elephant's foot at the side drift and an ongoing settlement trend was observed.

Below: **Mock up of the junction of the side drift**



Micropiles at the partially completed dome and along the temporary side drift were installed to transfer the load below the excavation level and reduce instability problems of bench/invert faces. This had immediate benefit in reducing ongoing settlement trends.

For the initial 10m of the inner tunnel, as the siltstone level was higher than the tunnel invert, the design of the tunnel profile was modified to socket the sprayed shotcrete lining into the siltstone. In simulating this profile, the socketing end was modelled as a pin joint with a small footing, which provides the bearing capacity.

For the design to work well on site, adequate quality control in ensuring that the rock layer wads sound and not heavily jointed was implemented. This ensured a good base for the loading to be transferred directly to the confined rock layer. There was little tunnel convergence monitored for this modified approach.

One safety benefit of this approach was that it removed the need for workers to excavate out the solid rock in the tunnel invert to achieve the original full ring closure. This would have resulted in significant vibration of the fresh shotcrete sealing layer above, causing a risk of falling shotcrete.

Table 1	
Total number of pipe (dia. 114mm, spaced 300mm)	48
Total number of pipe reaching the design length of 27m	46
Average aligned distance measured inside the executed pipes	23.9m

In the 3rd and 4th modules the top heading bench invert method was adopted with benefits on workability and productivity. The slowest cycle time for a 1m round has been 36hrs for the drift 1B during section A1 (within a mixed face of rock and soil) whilst the fastest has been 8hr for a top heading round in the Section A4.

Generally during excavation, problems of face instability have occurred mainly due to the unfavourable orientation and dips of narrow spaced strata and discontinuities, and the occurrence of distinct slip planes.

Soil nailing of the face was included in the design for the drifts 2A, for the top heading excavation and at the end of each tunnel section where a full face is formed. During construction soil nailing of the face has been extensively used also at all stages (1A, 1B, bench invert). The face nailing also helped as a confinement action in front of the face in reducing pre-excavation deformation. As a result, both in-tunnel deformation as well as surface settlement has been within the predicted design values, although a few settlement markers on surface exceeded the designed values that required a verification/assessment process by the designer (see Table 2).

Pillar stability

As mentioned, the pillar of soil between the twlo tunnels ranged between 1m and 4m. The stability of the pillar was a concern when excavating the second tunnel (outer tunnel).

LTA routinely appointed a board of international renowned consultants to review construction risk. The Board of Advisors advised that the permanent lining in the inner tunnel must be cast to increase the tunnel stiffness to improve the stability of this pillar before outer tunnel excavation could start.

The outer tunnel where the pillar is narrowest is now completed. The measures implemented comprise the casting of the side walls and base slab in the inner tunnel, the stitching of the two tunnels with tie rods,

Table 2

Station	Maximum settlement	
	During 1A&1B	During 2A&2B
A1-01	9mm	12mm
A2-01	15mm	19mm
A3-01	20mm	28mm
A4-01	20mm	34mm
	During top heading	During bench/invert
A5-01	22mm	25mm
A6-01	18mm	27mm
A7-01	10mm	12mm
A8-01	10mm	12mm
A9-01	7mm	9mm
A10-01	6mm	7mm

continuous face nailing ahead of the face and controlled excavation to minimise over excavation at the pillar side.

Conclusions

Both the side drift and top heading, bench, and invert (TBI) methods have shown to be successful in controlling the ground movements and avoiding excessive settlement, which could damage the existing utilities or public road.

he side drift method had been adopted for the first two larger modules of the inner tunnels, where a full top heading face would have been too large. The side-drift method presented some problems with workability, machinery access, space constraints, but with this system the inner tunnel module 1 (11.6m width tunnel with a cover of approximately 1 diameter) were successfully excavated with minimal deformations.

The TBI method used in the remaining portion of the inner bound tunnel has provided more working space and hence faster cycle time.

With the side drift method most of the deformation occurred during the temporary drifts excavations (1A/1B) and stabilised only once the full circular section was completed. Therefore the deformations on 1A/1B are sort of time related which might increase until the final stage of ring closure.

The top heading/bench/invert method resulted in generally lower deformation not only due to the reduced tunnel cross section compared to that of the side drift method, but also the formation of the temporary invert which immediately acted as a ring closure.

Micropiles have been shown to be an effective and easy method to increase the bearings of the ground below the elephant's feet and limit settlement.

Face nailing has also shown to be effective in order to maintain the stability of the face and to reduce the correlated hazards to an acceptable level.

No damage to the utilities has occurred as settlement of the utilities was within the designed slope values.

The pillar stability was ensured via making the first tunnel stiffer through casting the base slab and side walls, continuous face nailing of the outer tunnel, pillar stitching between the two tunnels and controlled excavation of the pillar side to avoid over-excavation. T&T

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Mechanized Tunnelling in Urban Areas – design methodology and construction control

Edited by Vittorio Guglielmetti, Piergiorgio Grasso, Ashraf Mahtab and Shulin Xu

We have all learnt that the best means of reducing tunnelling risk in the urban environment and avoiding the manifestation of that risk - adverse settlement, lies in the control of full face tunnel boring machines. But what is the best approach to controlling a TBM and what systematic and rigorous engineering controls should be employed? This book might well provide the answer for you.

This book details the state of the art of mechanised tunnelling in urban areas – by mechanised is meant the use of tunnel boring machines and systems of controlling these machines. It is so packed with information in this specialised field it is difficult to review without resorting to just listing its contents and allowing the reader to make his own judgement of the breadth of subjects covered.

The book is split into eight sections and appendices:

Introduction - A short history on urban tunnelling and an introduction to the books underlining theme of the Plan for Advance of Tunnel (PAT), the authors philosophy in establishing a risk management system that can best manage the risks associated with the advance of the tunnel face. The section stresses the iterative nature of tunnel design and the need to be able to refine design as construction proceeds.

Initial risks - An explanation of a formal risk management process based around systematic guidelines published by the International Tunnelling Association. The section, although by necessity generic, provides a good starting point in developing a project specific risk register. As well as listing generic sources of risk in mechanised tunnelling the section also details means of mitigating them. An explanation of the Decision Aids in Tunnelling is provided - a software system being a probability based program for estimating cost and time in constructing a tunnel taking into account uncertainty and risk associated with tunnelling.

Tunnel alignment - A review of the typical parameters that may influence the alignment of a tunnel and the ways of reducing risk by adjusting the alignment within a chosen corridor. Special consideration is given to the selection of an alignment to suit the passage of high velocity trains. The section is concluded by a consideration of space required for the contractors tunnel logistics, his launch sequence, worksite area and machine reception requirements.

A city machine and its essential characteristics - An overview of the principles to be adopted in the selection of an appropriate TBM together with a review of the typical types of machine and their characteristics available on the market.

Spoil conditioning is discussed in some detail and the section is rounded off by a review of the process of selecting either an earth pressure balance machine or slurry machine.

Tunnel design - The body of the book lies in this section – a civil engineers guide to the various issues arising from the detailed design of a tunnel. A review of the different methods of calculating tunnel induced settlement – the classical equations based upon an elastic analysis of the soil. Building condition surveys and Building Risk Assessment are covered together with calculations illustrating building vulnerability to settlement. A methodology for calculating face support pressure is included for the contractors tunnel manager, together with a consideration of grouting techniques behind lining and different grout mixes. This section also includes some fifty pages detailing the design of pre-cast concrete segmental lining and notes on how to cast them. What more could a civil engineering tunnel designer want?

Control of tunnel construction - Detailing the author's philosophy of the Plan for Advance of Tunnel – an iterative design scheme based upon initial prediction of ground behaviours being optimised by observation of the ground machine interaction. Essentially logging settlement data and machine data and refining machine drive parameters to reduce settlement if required. Means of controlling TBMs are considered in slurry machines as well as earth pressure balance machines.

Health and safety - A refreshingly short section on health and safety, its brevity in no way diminishes the importance the authors place on health and safety in the tunnel environment. The key to the section is an analysis of the special risks that tunnelling places on the health and safety of the workforce and the ways of mitigating those risks. Refreshingly enough there appears to be no reference to the word "Method Statement" in this section – a lesson that could be learnt by the UK construction industry. The emphasis is on establishing the nature of the risks and putting systems in place to mitigate against those risks. The section covers risks commonly encountered and is a good starting point for the tunnel manager in preparing his tunnel drive risk assessment.

Case histories - Six excellent case histories of urban mechanised tunnelling illustrating the development of the author's philosophy of the Plan for Advance of Tunnel and other interesting features of the drives. Projects include the SMART tunnel in Kuala Lumpur as well as schemes in France, Russia, Italy and Portugal.

Appendices - Highlights include lists of risks associated with urban tunnelling, a typical example of a worked excavation procedure for EPB shields.

Finally the book is wrapped up by an annex on the conditions of contract together with a proposal for the allocation of commercial risks associated with tunnel construction.

The book is an excellent read and would be an valuable addition to anyone's library of tunnel construction books. Despite the fact that the authors' mother tongue is not English there is very little to indicate this, although it must be said that some of the English although understandable may bring a smile to the face of a native speaker. The book is handsomely illustrated and builds upon systems developed in other technical publications such as the British Tunnelling Society's – Closed Face Tunnelling Machines. If any criticism can be levelled at the book, it is, that it is short on explanation of the mechanical and electrical engineering associated with mechanised tunnelling. The reader is left with the question of how do we further refine the process of mechanised tunnelling – what next?

Review by: Ivor Thomas
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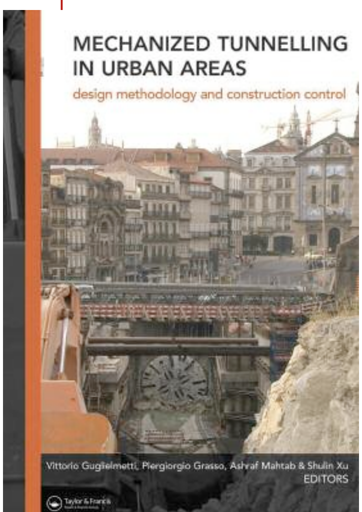
Published by: Taylor & Francis



RME at Guadarrama

Dear Sir

Having been involved daily in the construction of the Guadarrama Tunnels and as co-developers of the RME index, we noted with interest the letter from Dr Barton[1] commenting on the RME data we recorded at Guadarrama[2]. First of all, we would like to make it clear that the team which developed the RME has the highest respect for Dr Barton's remarkable professional contributions. No offense was meant in stating that we sought an alternative approach for assessing TBM performance.

For example, our tests of the uniaxial compressive strength of the rock materials involved at Guadarrama yielded the following different ranges of values (instead of one range 120 - 200MPa):

14MPa < gneiss < 110MPa (main rock formation present)
20MPa < granite < 127MPa
48MPa < porphyry < 172MPa
8MPa < Umbria fault < 31MPa (600m long).

Most of all, we wish to emphasise that there exists an important conceptual difference between the two methods employed to estimate the TBM advance.

In the case of the Q_{TBM}, the advance rate in m/hr is estimated by reducing the instantaneous penetration rate (PR) using a coefficient 'm', the physical meaning of which was difficult to envisage for us because our data at Guadarrama provided a different trend, as shown in Figure 1.

It seems to us that the step from PR to the average rate of advance ARA (m/day) depends, among others, on: percentage TBM utilisation; mechanical condition of the machine; and excavation strategy adopted by the TBM crew.

In reality, these parameters cannot be known with enough precision and, for this reason, we decided to employ statistical analyses for estimating the average rate of advance ARA, which is - please note - expressed in m/day but over many days in tunnel sections fulfilling the following conditions:

- Over its length, the section should have a representative RMR quality and should not produce significant variations in the values of the RME
- Over its length, the section should not include significant repairs to the TBM and its coefficient of utilisation should be between 30 to 70% of the time involved
- The minimum length of the section should be more than 30m
- The time period involved in completing a TBM section should be recorded in days, expressed to a decimal point

As the sections considered for statistical analyses are derived from different tunnels, the values of real ARA (ARAR) are consolidated to obtain a theoretical ARA (ARAT) using the above three factors, discussed in our article[2].

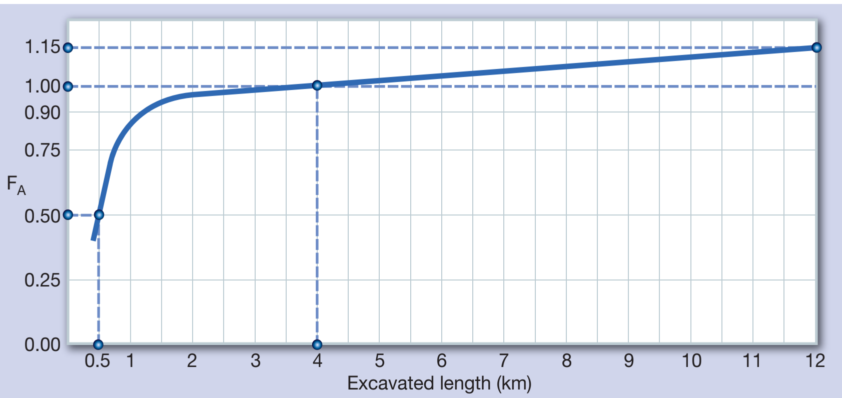
Applying this methodology, the correlations between the RME and ARAT, for three common TBM types, were found to have realistic values representative of the actual tunnelling practice and have similar high coefficients of correlation for all three types of TBMs.

The ultimate aim of the RME is to provide a reliable tool not only for estimating the machine performance but also selecting the type of TBM to be employed in a given tunnel.

Yours faithfully
Benjamin Celada, Jose Miguel Galera & Z T Bieniawski

Below: One of the TBMs and the face, on Spain's Guadarrama Tunnels

Below: Fig 1- Increase in TBM performance (co-efficient FA) with the excavated tunnel length at Guadarrama



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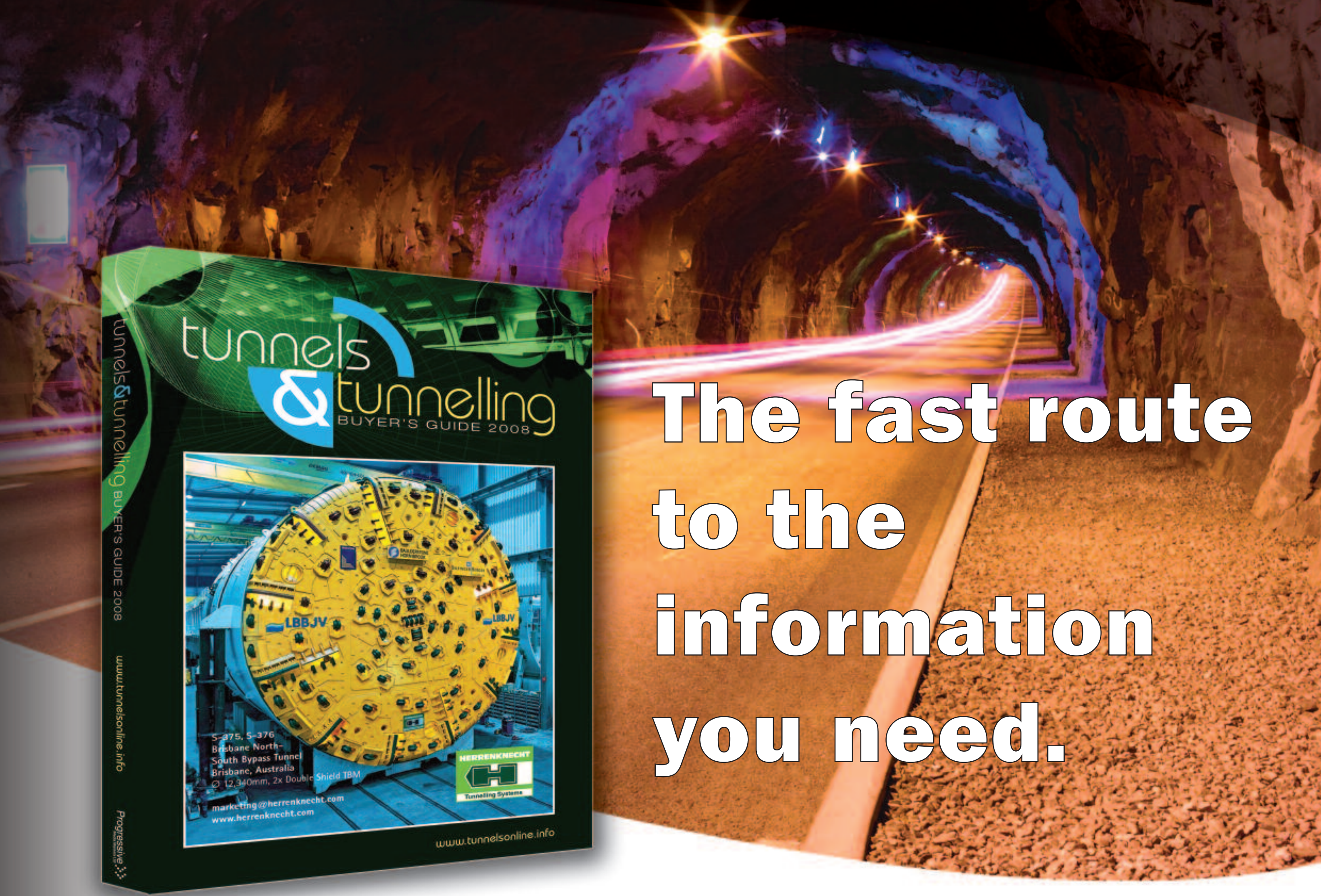

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AD

Drill and blast in confined spaces

At the joint meeting of the BTS and MinSouth on 21 February 2008, Richard Soloman, project manager for WECS, Damian McGirr, of Donaldson Associates, and Mark Thomas, site manager for WECS, described the drill and blast works on an urban flood alleviation tunnel in Bristol, UK

In the past year flooding not only hit the headlines but caused considerable damage and upset to those in many of the UK's low lying areas. One of these is Bristol City centre, an area recorded on the OFWAT register as susceptible to flooding, and the subject of one of Wessex Water's 400 schemes in its five-year capital programme to relieve sewer flooding. The Bristol project has a number of interesting challenges related to the city centre infrastructure, access, topography and underlying geology.

Wessex Water, has its own engineering company, Wessex Engineering and Construction Services (WECS) who undertakes major capital works. WECS had experience in the area in the construction of the northern interceptor sewer that drains the north part of the city and was the main contractor for the works. Design work for the city centre flood alleviation was undertaken by Donaldson Associates and included route alignment, site investigation, and tunnel design. Specialist Engineering Services Ltd (SES), was appointed tunnelling contractor for the project who engaged Parsons Brinckerhoff for design of temporary works.

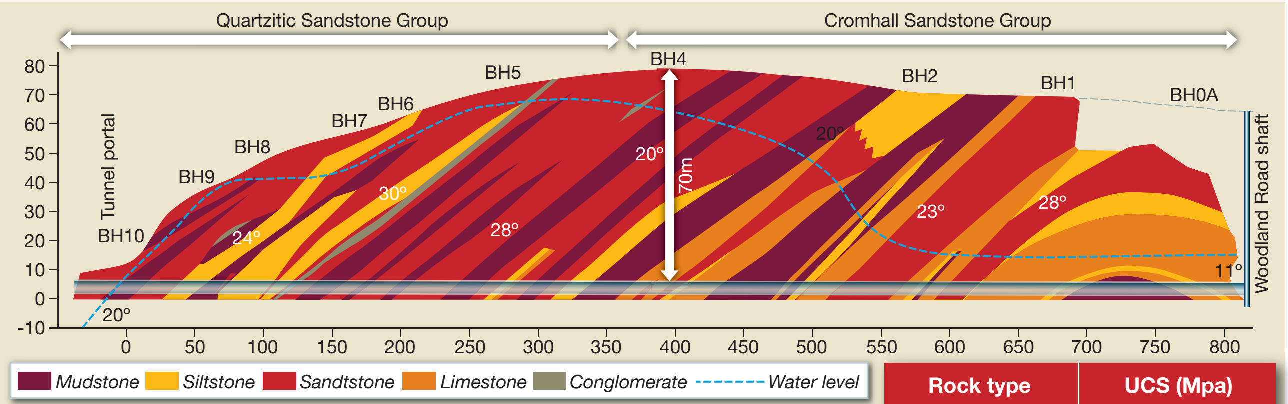
Richard Soloman, project manager for WECS gave an overview of the project, Damian McGirr lead for Donaldson Associates presented some of the issues in design and Mark Thomas Site Manager with WECS updated on construction progress.

The project options

The 57 properties included on the flood register included the Hippodrome theatre and a number of historic shops and houses. Bristol City centre is a mixture of Georgian and Victorian architecture linked by busy narrow streets. There are a number of in-fill buildings such as multistory car parks and an ice rink. To the south of the city is the historic floating harbour while to the north is the University of Bristol. A number of possible solutions for flood alleviation were considered including distributed storage; upsizing existing sewers; construction of a major pumping station; the construction of a new combined sewer overflow; and the boring of a transfer tunnel. As Richard Soloman, WECS project manager commented, "the preferred option was not obvious but the result of careful balancing of demands and responsibilities".

Distributed storage of floodwater (for later pumping) was eliminated because there was insufficient land within the city centre for the 4500m^3 of storage on three sites required. Odour may also have been a problem with this option. The upsizing of existing sewers was also discounted on the interruption to road and services that enlarging would entail and also on capital cost considerations. Construction of a new combined sewer and pumping station was also unfavourable because of capital cost. This left the construction of a 800m gravity transfer tunnel to the northern interceptor north of the city centre. The selected solution had the advantages of a single site for a tunnel drive with straightforward land issues, it was sustainable (requiring no pumping), minimised likelihood of odour, virtually eliminated spills into the harbour

Below: Fig 1 – Plan map of the project area, in the centre of Bristol



Above: Fig 2 – Longitudinal geological section of the tunnel alignment

Rock type	UCS (Mpa)
Limestone	136 to 286
Sandstone	159 to 487
Siltstone	
Mudstone	<50

and with capex of US$19M had the lowest whole life costs.

Soloman continued, "WECS was charged with finding and constructing the tunnel drive shaft within the city centre to connect the existing sewers to the new tunnel. A narrow 9m site was found between the Ice Rink and a multistory car park that with careful planning would do. Its main advantages were that it did not block access and had no residential neighbours. Its size was its major disadvantage" he added.

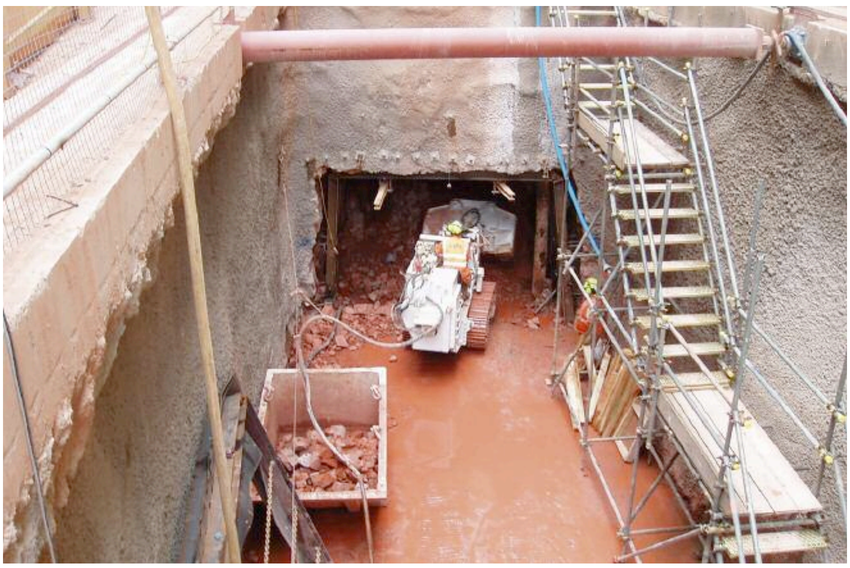
Once this decision had been taken Wessex Water engaged Donaldson Associates to carry out detailed design of the tunnel from the city centre to the northern interceptor. Overall the tunnel is 805m long and up to 70m below ground at its deepest point with the majority around 60m. Obtaining permissions was facilitated by the fact that for most of its length it is beneath one owner, the University of Bristol. McGirr also noted that "there were a number of historic buildings including Royal Fort with intricate plaster work." There was also very sensitive equipment used for detecting earthquakes in the Bristol University Laboratories. In areas where cover was lower there was some concern that residents would be affected by 24hr tunnelling operations. A significant challenge was considered to be the connection into the existing shaft of the Northern Flood Relief sewer at the 63m deep 3.66m diameter shaft in Woodland Road.

Early works and geology

The first activity was to carry out site investigation along the route. Twenty boreholes were sunk to a maximum depth of 93m. These holes supported downhole geophysical measurements and the core recovered gave vital insight to the subsurface geology. The bedrock geology was a combination of quartzitic sandstones, mudstones, siltstones, limestones and minor conglomerates of the upper Carboniferous age. Above the tunnel, ground thicknesses varied from 10m to 80m. These rocks gently dip at about 20^{o} along the tunnel line and as a consequence the tunnel line cuts through this succession which ranges from very hard and strong rocks such as the quartzitic sandstones (with strengths up to 487Mpa) to soft mudstones. Hydrologically the latter acted as barriers whilst the more permeable sandstones acted as conduits for ground water that entered the tunnel during construction. Another feature of the dipping geology was that during tunnelling the rock broke in a blocky fashion controlled by the bedding and jointing.

The geology according to McGirr became a major factor in determining the construction method, which in turn had a major impact on tunnel size. A minimum 1.5m diameter tunnel was required for the project design flow of 2000 litres per second. Consideration of health and safety for a tunnel drive of this length increased this to 1.8m minimum diameter, but 2m was preferred for operation activity. In fact, a much larger area of excavation 4m wide was required for construction machinery access. The permanent 2m diameter tunnel lining is still being finalised but it will need to withstand water pressures up to 6bar and have a design life of 60 years. Options being considered are: in situ structural lining with collapsible shutter, sacrificial shutter (weholite pipe) infilled in stages by foam concrete or using precast concrete pipe.

Below: The project shaft with muck out in progress



Method selection

Selection of a construction method was made following on from submissions from contractors at tender. Three main areas of risk were assessed in comparing the options:

- project completion risks
- health & safety risks
- contractual/commercial risks

The potential noise and vibration of blasting was an issue. The removal of a TBM at the connection point to the Northern Flood

Relief Sewer would have been challenging and costly with some health and safety risk. It was considered that the drill and blast method gave greater confidence that the tunnel would be completed within a reasonable timescale and budget. It offered greater flexibility in terms of dealing with the interbedded geology and in particular the extremely strong sandstone (almost 500MPa) to weak mudstone. Requiring more work within the tunnel, the drill and blast method had the greatest health and safety risks, and it was considered that these could be managed by the implementation and control of safe systems of work. There was also local experience of constructing tunnels by this method in similar ground conditions. In addition the drill and blast option was more cost efficient with a very similar programme to the TBM option.

The works

Design of the drive pit located on a narrow strip of land between an Ice Rink and Car Park was challenging with depth to rockhead varying from 1 to 7m. It was sized to accommodate a 4m span tunnel. A rectangular pit 15m x 6m serviced with a Gantry Crane was used.

Surface works began in the second quarter of 2007 with construction of the city centre surface works and the drive shaft by WECS. According to construction manager Mark Thomas, one of the constraints was the working hours: 24hr working Monday to Friday, with blasting window 07.00 to 23.00. Blast vibration was limited to $10mm/s^2$ ppv monitored at the closest property. This is above that that can be felt (approximately $1.5mm/sec^2$ ppv) but well below that where minor damage to buildings occurs ($45mm/sec^2$ ppv).

The initial work says Thomas 'was related to clearing the shaft area in the 9m gap between the car park and the ice rink. Because of the variation in depth to rockhead the pit was reinforced by 40 x 300mm diameter steel piles and with concrete waling beams. A 25 ton excavator was lowered into the shaft to carry out most of the excavation with a smaller 3 ton machine used for trimming. Shotcrete was used to finish the walls of the shaft.

Drill and blast cycle

The tunnelling cycle was drill, blast, re-entry, clean and support" he added. The first 60m of the tunnel is a rectangular section 4.5m x 3m with the remainder 3.5m x 3m. These sizes allowed the passing of the mucking out haulage and the jumbo drilling machine whilst avoiding the necessity to back-up the drill rig excessive distances for cleaning out the blast.

Above: **The jumbo drill rig working at the face**

In the narrower section passing bays were excavated at suitable intervals. The tunnel is supported by steel sets.

Safety issues are very important maintained Thomas, "we monitor a wide range of gases in the tunnel including methane, NOx and carbon monoxide. Using explosives requires air flushing and we have a 900mm forced air ventilation duct". The blasts are also monitored by camera to confirm correct sequencing of the charges and to keep vibration within the agreed parameters. Explosives for the blasting are stored in a secure site 20 miles away and delivered by two vehicles monitored remotely. Blasting has caused the minimum of disturbance to the city and its residents.

Progress to date was 117m, which is approximately a 6 week slippage on programme, however mitigation measures have been taken. Mucking methods were changed with the aim of bringing the project back on programme. Scheduled completion is April 2009, when risk of flooding in central Bristol will be removed for many properties. T&T

QUESTIONS FROM THE FLOOR

Barry Couchman (London Bridge Associates) asked about the reasons for the large rectangular section of tunnel requiring large quantities of concrete. Mark Jones remarked that the size was determined by the size of the plant required to construct the tunnel and selected by the contractor. The rectangular section has naturally occurred due to the dip orientation parallel to the tunnel alignment.

Phillip Wall (Network Rail) asked what parameters are looked at in the weekly inspection of the supports. Mark Jones reported that the temporary works designer is inspecting weekly, site staff are monitoring as built section, and convergence of supports and rock quality is undertaken on a daily basis by the contractor's staff.

Terry Crabb (LBA) asked about the structural function of the piles in the shaft at 3m centres with the freestanding rock and whether there are limits on dewatering. Damian McGirr agreed that rock is freestanding, but there is a need to make absolutely sure there is no settlement of the car park. The piles also support a beam supporting the gantry crane. There were no limits on dewatering, but despite the 60m water table, ingress of water has been limited because the mudstone acts as a dam limiting duration of inflows.

Andrew Smith (Joseph Gallagher) asked about appointment of the clients own construction division WECS. How is best value ensured and what contract is used? Richard Soloman responded. WECS costs are benchmarked and monitored and compared with other construction data to ensure value. SES has been engaged on an NEC cost reimbursable basis for the first 50m where expected rates of progress were uncertain, then on a target basis.

Duncan Wardrop (Lafarge Aggregates) asked about the vibration experienced and the maximum instantaneous charge for blasting. Mark Jones reported that $5.9m/s^2$ ppv was achieved today with a charge of $1kg/per/m^3$.

Rod Young (Barhale) inquired about cycle times achieved and shift cycle. Two 11hr shifts are worked with 9hr cycle times at present commented Mark Jones.

Helen Natrass (Sir Robert McAlpine) asked about noise limits in hours of darkness and how it affected the work. Mark Jones remarked that this hadn't been a problem as there have been high night-time noise levels (78dB) from a night club in the locality.

Rapporteur: Michael Francis

Speed up a long way.

Niagara Falls/Canada. For the construction of the 10,500m long Hydro Power Tunnel the conveyor providing company H+E supplies a continuous conveyor system allowing a fast transport of the excavated material. One Booster is used to reduce the forces exerted on the belt along the route; with the pleasant side effect to guide the belt save in front of a vertical curve.

The naked facts:

Tunnel diameter:	14.4m
Conveyor length:	10,500m
Belt width:	1,000mm
Capacity:	1,600 t/h
Installed power:	4 x 360kW (head) 2 x 360kW (booster)
Belt storage capacity:	600m of belt
TBM:	Hard Rock Gripper
Installation:	2006
Contractor:	Strabag Inc.

H+E LOGISTIK GMBH

H+E Logistik GmbH
Josef-Baumann-Straße 18
D-44805 Bochum
Germany

phone + 49 (0)234 | 950 23 60
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www.helogistik.de

High-tech conveyor solutions


The vertical and enclosed-horizontal conveyor set-up for the East Side Access project

Hi-tech tunnel conveying systems can offer unique solutions to complex site and transport logistics. Deputy editor, Amanda Foley, looks at some recent projects case histories

Severe restrictions on the amount of space available on site, around portal areas and within shafts, is commonplace in today's industry. Every job faces its own difficulties, but with a growing number of transport and utility projects in highly-urbanised areas - as well as the number of high-speed rail and hydroelectric projects being constructed in isolated or environmentally sensitive areas - organising the removal of muck from long, or multiple, tunnel drives can seem as much of an engineering challenge as the actual excavation itself. Increasingly, high-tech conveyor systems are able to offer practical and flexible solutions to many of these logistical issues.

Site solutions

"We have become quite creative in overcoming limitations in shaft or site space," says Dean Workman, vice president of conveyor systems for Robbins. "In general, there are many options available for conveyor design and we are always able to work with specific site restrictions."

For instance, on the East Side Access project, in New York, contracting JV Dragados/Judlau is mucking its Manhattan rock tunnel drives via a Robbins conveyor through the existing 63rd Street immersed tube tunnel, emerging at an open-cut box at the Sunnyside rail yard, in Queens (*T&TNA*, Dec 2007, p8).

In order to reach the temporary storage area, on the other side of the site, the conveyor has to rise up and traverse a four-lane highway, passing underneath the Northern Boulevard aerial rail corridor. "In order to achieve this, we designed a series of cascading conveyors, plus a completely-enclosed conveyor to cross the highway," says Workman.

Vertical conveyors were also utilised on the UK's Lower Lea Valley Cable Tunnels. One of the main logistical challenges here was the limited space available at the project's central twin mining shafts (*T&TI*, June 2007, p18). With each of the 15m diameter shafts being used to muck and supply two separate Lovat EPBM headings, in highly-variable ground, the only way to safely manage crane operations in the shafts while also efficiently emptying the side tipping muck skips, was to adopt the use of High Angle Conveyors (HACs). Manufactured by Continental Conveyor, and supplied and serviced by Burrows Brothers, the HACs' belts were fed from sumps incorporated into the base of each shaft during construction.

Contractor J Murphy & Sons has openly applauded the performance of the HACs, saying the extremely tight project schedule could not have been achieved without their use. There was a risk involved in the strategy adopted, as Murphy's senior contracts manager Bob Brown admits: "There simply wasn't a 'Plan B' if the HACs didn't work out for us. It was a big decision, one that had to be taken very early on in the project. But under the same circumstances it's definitely something I would do again."

Pierre-Alain Scherwey, of Swiss-based manufacturer Marti Technik, agrees conveyors can offer very smart solutions when shaft space is tight, particularly for deeper shafts, but he also points out the additional benefits of using conveyors to move muck around or off a site: "Conveyors can free up a lot of space on the job site, allowing more room for construction traffic," he says. "They can also transport muck long distances off-site for final disposal - negotiating roads, rivers and any other kind of obstruction."

Such traversing techniques will be used in abundance on China's Jinping II Hydro Electric Scheme, where Marti Technik subsidary, Marti-Xui Engineering, is currently constructing a huge conveying system on a steep valley side.

Marti-Xui's contract includes the design, manufacture and assembly of over 6000 tonnes of steel structure to support the tunnel conveyors and main external conveyor. A number of suspension bridges



Right: **Continental's HACs in use on the UK's Lower Lea Valley Cable Tunnels**

and even a section of tunnel will also be required to negotiate the 7km journey to a processing facility further down the valley. The system has been designed to transport muck at a rate of 5000 tons/hour from five different tunnels, including three TBM drives and two drill & blast headings. At the same time, the return belt of the system will bring concrete aggregates back up from the processing plant to the concrete plant.

Following commissioning of the system, this summer, a total of more than 25,000,000 tons of muck and aggregates are due to be transported on the system.

New lengths in India

Longer conveyor systems are indeed becoming increasingly common features. "There has been quite a lot of interest in using belt conveyors for overland transportation recently," says Workman. "The cost of using trucks to move spoil has gone up dramatically, both for petroleum-based tires and the large amounts of fuel that such vehicles require." Conveyors offer cost savings in this respect, and have the added environmental benefit of using electric motors rather than diesel.

A recent Robbins conveyor design, made for the Pula Subbaiah Veligonda Tunnel #2 in India, tops out at 19.2km in a single conveyor flight. The contract, awarded by Coastal Projects Pvt, also includes the supply of a 10m diameter Double Shield TBM and back-up system.

The water tunnel will follow a straight path through quartzite, shale and phyllite and will travel underneath India's largest tiger sanctuary - the Nagarjunasagar Reserve. Both the tunnel length and environmental concerns including excess noise and exhaust meant that conveyors were the only feasible option for muck removal.

Left and below: **The ability of conveyor systems to traverse steep valley sides, rivers and roads, can offer big advantages for large-scale projects such as the Jinping II HEP**

"Conveyors are the most non-invasive method compared to locomotives and muck cars, which are often noisy and emit exhaust during operation. The trains also require more maintenance and are less efficient on longer tunnels, where they must keep up with the excavation rates of high-powered TBMs," says Workman.

As a result, long tunnel projects using continuous conveyor systems rather than muck cars often experience higher rates of system availability. For example, the Epping to Chatswood Rail Link tunnels in Sydney, Australia, achieved an average rate of 94% system availability with continuous conveyors, despite the extensive tunnel lengths and more than 80% of the bore path being curved.

The design of the Veligonda conveyor system is also tailored for maximum efficiency. The system, consisting of the longest conveyor drive Robbins has ever provided, will allow maintenance and belt splicing to be performed outside of the tunnel in an optimal environment. To take the belt to greater lengths, more powerful drives are needed as well.

The steel cable belt system will be powered by a total of seven drive motors - one main drive with two 300kW motors at the tunnel portal plus three booster drives with a total of five motors inside the tunnel.

"In theory, we can make still longer conveyor systems, though this will depend on the tunnel alignment and the expected capacity of the conveyor system," explains Workman.

Conveyor components at Veligonda can be interchanged with those of its sister tunnel, the AMR Project, contracted to Jaiprakash Associates by the Andhra Pradesh government. The tunnel sites are two to three hours away by road and will utilise nearly identical conveyor systems, making exchange of belt rolls and other parts relatively easy. The scheme is part of Robbins' goal to create universal components for as many conveyor systems as possible, though this is necessarily limited by variables including belt width and tunnel alignment.

Variables in each conveyor system are determined by the contractual penetration rate of the TBM - a higher penetration rate will require a wider conveyor belt to handle more muck, for example. Excavation rates established depending on rock type, rock hardness, machine type, and a host of other factors. The AMR and Veligonda Projects will utilise nearly identical Robbins TBMs and will bore through similar rock, resulting in the same expected penetration rates and interchangeable conveyor systems using 914mm wide belt.

"The design of these conveyor systems looks to be simple and user friendly, though the efficiency still needs to be tested as the projects start up," said Anil Kamat, project manager for Jaiprakash at the AMR jobsite. Once complete, both Veligonda and AMR Projects will become part of a larger system to draw floodwaters from the Krishna River for irrigation and drinking water. The water will be distributed through a network of canals to over 400,000 acres of farmland and villages in the arid state of Andhra Pradesh.

Keeping Katzenberg clean

The new 9.4km long twin-tube Katzenberg Tunnel forms a central element of the current Rhine Valley Railway upgrade between Karlsruhe, in Germany, and Basel, in Switzerland. Already a key route for national and international rail traffic, once upgraded the line will also provide access to the Alpine rail routes (NEAT) currently being built in Switzerland.

Right: **AMR's conveyor system shares common components with Veligonda's**

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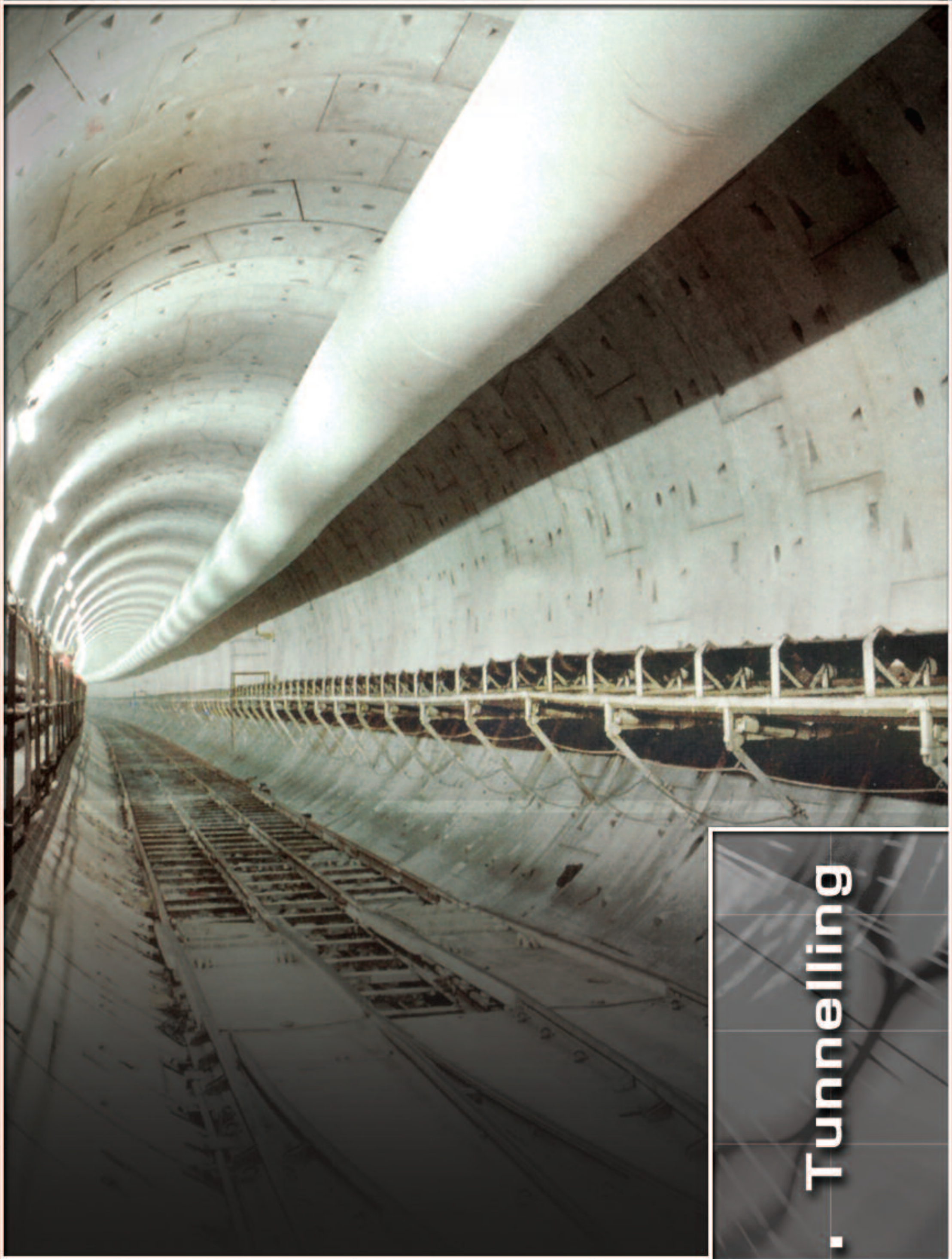

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Left and below: Katzenberg's portal area, showing the installation of the Marti Technik conveyor system and temporary muck storage

A JV of Ed Züblin, Wayss & Freytag, Marti Tunnelbau and Jäger Bau completed excavation of the 9385m twin-tube tunnel in October last year, using two 11.12m diameter Herrenknecht EPBMs. Launching the first machine on the East tube in May 2005, and the second on the West tube in the September, the Katzenberg TBMs drove north through the region's limestone, sandstone and marls, at depths of up to 110m (*T&TI*, November 2007, p7).

The strategy for disposal of excavated spoil from the twin parallel tubes, and the selection of a suitable system for charging the final disposal site, placed big demands on the project in the planning phase. A particular challenge was that excavated material could only be transported to the final disposal site, 2.5km away at the 'Kapf' quarry, during restricted time periods. This meant that an environmentally-sensitive temporary muck holding site would also be required on site.

In collaboration with the JV, Marti Technik designed, manufactured and assembled a complex mucking concept, that focused on operational reliability and ease of maintenance. "We design all our conveyor systems with the help of software that enables us to simulate any scenario on-screen. This allows us to determine the most appropriate components and system features for each element of the conveyor."

Thanks to a near straight tunnel alignment, Katzenberg's two 9km long continuous conveyors could operate the full tunnel distance with a single-pull system, powered by head units at the portals - avoiding the need for additional boosters. This greatly reduced servicing and maintenance requirements in the tunnel.

The conveyor also included a high-performance control command system, that can collect data from numerous sensors and transform it into information that can be used to improve performance.

"The sensors detect hopper or belt overloading, return drum rotation defaults and even whether or not the conveyor structure is assembled correctly for the next TBM advance," explains Scherwey. "Everything, including video monitoring, is visible via control screens in the TBM cabin and in the control centre on the surface. This helps the contractor to improve on performance and site organisation."

Safety of tunnel personnel was also considered during the conveyor design. "We design all access, working and maintenance areas with safety in mind," says Scherwey. Walkways are all anti-slip, with handrails, and steps and stairs are used instead of ladders. There are also grills over all the rotating parts and extra room is provided around the belt scrapers for maintenance. Emergency stop buttons, lockout systems, warning lamps and sirens are also located at regular strategic points along the conveyor.

Into the future

The technology, reliability, safety and cost of conveyors has much improved over recent years, with key suppliers plowing a huge amount of accumulated project experience back into their design and production processes. Higher quality components, due to tighter manufacturing tolerances, play a big part in increased performance. "What determines the power and efficiency in a given system is how much friction is present," says Dean Workman. "Better components take less resistance to run and use less energy, which means longer lasting systems." Workman also credits variable frequency drives with Programmable Logic Controllers (PLCs) as another recent improvement, as they control the output torque: "In very long, multi-drive conveyors systems with booster drives, for example, the PLC can balance loads on each drive to maximise efficiency."

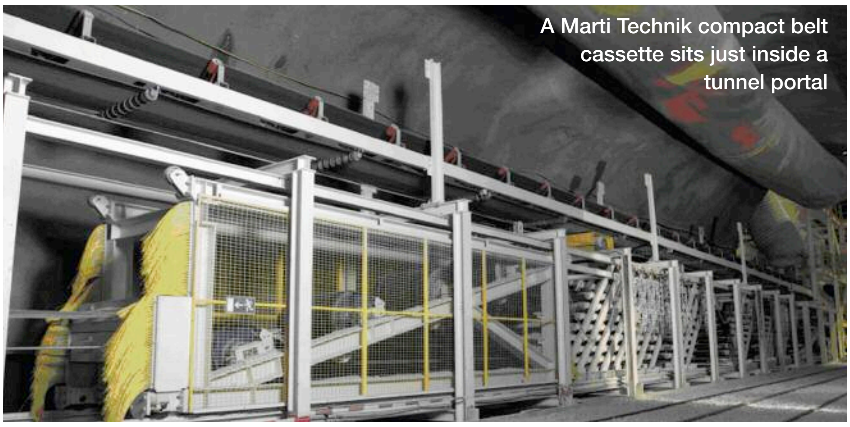
The costs of conveyors are also being reduced by manufacturer's efforts to standardise components and simplify system designs. Refurbishment of existing systems, and bespoke rental systems fitted with refurbished second-hand components, are also a key revenue streams for conveyor manufacturers and suppliers.

"On rentals, we guarantee machine availability, provide and guarantee wear and spare parts, splicing tools and materials, and also provide on-site training," says Scherwey. "Ultimately, we want to provide a very interesting global cost, along with reliability and performance."

In terms of possible future developments, Dean Workman believes there are two main areas that will soon impact: Even more advanced electronic controls; and new developments with conveyor belting.

"For controls, there will be better monitoring of the entire system. This is already happening to some extent - on East Side Access data is recorded on a laptop in New York, which we can access from our office in West Virginia. We can view the entire system, making troubleshooting easier.

For belts, new designs will include embedded computer chips to provide additional monitoring. Data including when the belt was installed and how many times it has cycled through the system can be used for maintenance. Currently engineers are still working on developing a computer chip that can withstand the heat and pressure of the belt manufacturing process, but once this is achieved we will know much more about the systems at any given time." T&T



A Marti Technik compact belt cassette sits just inside a tunnel portal

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Transport news

Brightwater's blast-proof locos

Brookville Equipment Corporation is building three 20 ton explosion proof locomotives for the joint tunnelling venture of Jay Dee/Coluccio/Taisei Contractors. These locomotives are destined for the Brightwater Project, a new sewage treatment facility located in King County near Shoreline, Washington.

These locomotives will feature the Caterpillar 3306PCNA 6-cylinder 150hp permissible diesel engines. The liquid cooled engines are mounted to a Clark torque converter and powershift transmission. This gives the locomotive the best available drive line to power the Rockwell planetary axles. The units also have premium stopping power from the sealed wet disc brake system, which also provides a long, maintenance-free service life.

These Brookville locomotives are designed to operate in a gaseous environment, which requires that Brookville reduce the locomotive's opportunity to provide ignition to the ambient air. Each unit's engine's exhausts are blanketed and the patented exhaust treatment system cools and filters all emissions. The unit also uses sealed lights, control panel indicators, and other electrical systems designed to eliminate the possibility of sparks.

The Brightwater Project, slated for completion in 2010, is using Brookville's locomotives in 20.8km of tunnels, with depths ranging from 13-158m deep.

Brookville Equipment
Tel: +1 814 849 6026
Web: www.brookvilleequipment.com

Space saving separation plants

AKA-SEP separation plants are, says the company, optimised for the specific needs in tunnelling and microtunnelling. Claimed features and advantages of the AKA-SEP and AKA-TRONIC technology include:

- Space-saving design in 6.5m container frames
- Constant low cut-point, even with widely carrying solids concentration, due to changing geology and TBM speed
- High solids separation rate at minimum bentonite loss
- Consistently high thickening rates in the hydrocyclone underflow (>1200g/l)
- Effective dewatering of the hydrocyclone underflow
- 'Cake' fines filtration on top of the pre-separated coarse material
- Large classifying and dewatering screens
- Substantial energy savings (>25%)
- Less wear and spare parts, and lower maintenance requirements due to one single pump
- Short set-up times
- Relief of the downstream dewatering equipment (in case a centrifuge is required)
- Savings in flocculent consumption (in case centrifuge is required)

Capacities per unit include 200, 400 and 800m^3/h. By clustering the standard units every required capacity can be achieved, AKW says. AKW A+V also designs project specific separation plants.

AKW Apparate + Verfahren
Tel: +49 9622 7039 0
Email: akwauv@akwauv.com
Web: www.akwauv.com

Do the locomotion

For more than a century Irwin Car & Equipment has been designing and manufacturing material handling equipment for the underground mining and tunnelling industries – offering battery and diesel locomotives, muck cars, lift off or Granby style supply and personnel cars, as well as an extensive variety of specialty cars.

In addition to designing and manufacturing new rail-based haulage equipment, Irwin Car also specialises in the refurbishment of existing locomotives and cars, sourcing surplus equipment and supplying replacement parts.

"Irwin's extensive in stock inventory includes items such as king pins and centre plates, wheels and wheel assemblies, rubber springs and outboard rollers, Willison couplers, draft gears and tailbolts," the company adds.

Irwin Car & Equipment
Tel: +1 724 459 6814
Email: kbartholow@irwincar.com
Web: www.irwincar.com

Adapting segment cars at Turin

Italian manufacturer Paolo De Nicola recently announced the delivery of three 27t segment rubber-tired low carriers to ML3000 Scarl, a joint venture company consisting of Maire Engineering (Maire Tecnimont Group) and Ghella, for construction of the Piazza Marconi to Lingotto section of Turin's Metro.

Close cooperation between the JV and Paolo De Nicola enabled the best solution, in relation to the characteristics of the project, to be selected. The result is a highly customised machine that can follow the tunnel's slope and grade, adapting wheel groups to the curved surface with a good pace of diesel-hydraulic translation.

The unit has a compact design suiting the selected TBM backup, with double cabins for driving in both directions, space for transport of other equipment, attention to comfort and safety of workers.

Paulo de Nicola
Email: mail@paolodenicola.com

Rolled into one

Since Rulmeca acquired Melco South Africa at the end of 2006, it has integrated its products, including the Supreme roller, a high density polyethylene roller designed for corrosive and abrasive applications, into the Rulmeca Group companies.

The Melco Supreme claims a wide range of superior advantages, features and benefits. These include: Steel tube to ensure adequate mechanical strength for heavy-duty loads; thick (12mm) abrasion- and corrosion-resistant HDPE sleeve; HDPE that contains carbon black to increase ultra violet resistance; a steel and HDPE tube combination to reduce weight; a bearing housing that effectively locks the HDPE tube in position, preventing movement along the steel tube; minimum "C dimension" to decrease load induced shaft deflection; large diameter stoneguard with integral labyrinth design that minimises the possibility of jamming by spilt material, and provides additional protection from water and dust; a multi part labyrinth seal to protect the bearing from ingress of contaminants; low running resistance and break away mass to reduce power consumption for start up and continuous operation; a machined finish that ensures low run-out, minimising emissions.

Rulli Rulmeca
Tel: +39 035 4300111
Email: rulmeca@rulmeca.it
Web: www.rulmeca.com

Flexible rolling stock solutions

Mining Equipment recently supplied a full train of rolling stock to the Interceptor Fucha-Tunjuelo in Bogota, Colombia, being excavated by Consorcio Interceptor Fucha-Tunjuelo (IFT) for Empresa de Acueducto y Alcantarillado de Bogota (Bogota water and sewage company). The full train of rolling stock consisted of: muck cars, grout cars (hydraulic drive), segment cars, flat cars and personnel carriers.

Mining Equipment personnel had to accommodate multiple conflicting factors; back up gantry window (limiting the width and height of the cars), volume capacity required (for the muck cars, grout cars and segments), crane capability and a restricted box cut portal (the weak, unstable ground not allowing for a back shunt).

To accommodate the train length the portal switch had to be located inside the tunnel. Twin 25t gantry cranes lifted and dumped the 8 cubic meter lift off muck cars and placed segments and ancillary equipment into the 15m deep box cut. At time of writing 500m of the 10,000m tunnel is completed.

In addition, Mining Equipment has also supplied Thiess with a complete spread of rolling stock for the Sydney Cable Tunnel, in Australia.

Thiess is using completely refurbished 15-Ton Plymouth Locomotives. The locomotives were narrowed to 1350mm and brand new water-cooled Deutz engines were installed.

They are using new 10-cubic yard capacity lift-off muck cars. They also have personnel carriers and flat cars that fit the muck car chassis to help minimise costs and make spare parts easier to manage. The segment cars also utilise a common wheel and axle set to make parts procurement easier. All equipment is being rented for the project.

Mining Equipment offers the complete package

Mining Equipment
Tel: +1 970 259 0412
Web: www.miningequipmentltd.com

Powerful rail transport

Besides two-axled tunnel locomotives from 5 to 45 tonnes, Schöma also designs special traction systems for steep gradients of 4-7%. The system consists of one locomotive with one or two driven platform cars. The drive system is hydrostatic with the vehicles connected via high-pressure hoses. The vehicles are two-axled or four-axled bogie type with a weight up to 60 tonnes and the platform cars are designed to carry muck, mortar or gravel containers in order to increase the adhesion and traction capacity.

The locomotives are equipped with diesel engines up to 500hp and comply with exhaust emission regulations. Schöma says the hydrostatic transmission enables wear-free braking of the train supported by an additional electro-magnetic retarder brake, so that the consumption of brake blocks is reduced to a minimum.

The locomotives are controlled by a microcontroller PLC system developed by Schöma. This comprises synchronised operation of locomotives with two or more units operated by one driver, wheelslide detection and CANBUS communication.

Schöma
Tel: +49 5441 997-0
Email: sales@schoema-locos.de
Web: www.schoema-locos.de

Separation solutions from PSD

Solids liquids separation plant specialist PSD, from the UK, is adding yet more high-capacity S4-1-G and S5-1-G centrifuges to its rental fleet, said to be the largest of its kind in Europe.

The centrifuges are specially upgraded to PSD's specification and are controlled by Allen Bradley computerised control systems, with bespoke programming for heavy-duty civil engineering applications.

The S5-1-G centrifuges are 1100mm in diameter and have a 3300mm long bowl unit, with variable-speed drive powered by a 160kW motor with inverter control. A twin start scroll is driven by a variable speed 55kW motor with inverter control.

An optimised design sees the centrifuge housed within a heavy-duty frame, which allows it to be shipped as 20' ISO container units. In use, the centrifuge module partially cantilevers over the end of the powerhouse module and the solids discharge from the underside of the cantilevered section.

The powerhouse module houses the PLC, control screen and keypad, inverters and control gear for the centrifuge and for the variable speed LM100 peristaltic pumps used to supply mud to the centrifuge. The powerhouse module also includes a tank compartment in to which the centrate discharges by gravity and a variable speed Metso HM100 pump, with 22kW motor powered from an inverter, is used for the discharge of the centrate from the tank. The S5-1-G centrifuge is fed mud by LM100 positive displacement peristaltic pumps, each with a variable speed drive powered by a 22kW electric motor.

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Dates & Events

22-24 APRIL
5th International Symposium on Sprayed Concrete - Wet Mix Lillehammer, Norway
Organised by the Norwegian Concrete Association, main themes will be design, construction and durability of wet-mix sprayed concrete. Results from the Hanekleiv investigations, will also be presented. Contact: Email: info@sprayedconcrete.no; Web: www.sprayedconcrete.no

4-7 MAY
13th Australian Tunnelling Conference Melbourne, Australia
"Engineering in a changing environment" is the topic of the 2008 Australasian Tunnelling Society conference. The present buoyant market conditions in civil infrastructure and mining Australia and New Zealand promise a great programme. Contact: AusIMM; email: dedwards@ausimm.com.au; web: www.atstunnelling conference2008.com

20-22 MAY
Intertunnel 2008 Turin, Italy
This bi-annual international exhibition will focus on major projects in Italy. The show promises to be an excellent networking environment. Contact: Olivia Griscelli, exhibition director: email: intertunnel@mackbrooks.com; web: www.intertunnel.com

29-30 MAY
Second Seminar of CPT "Tunnels and Underground Works in Portugal", Lisbon, Portugal
Organised by the Portuguese Committee on Tunnelling (CPT). Contact: Catarina Luis. Tel: +351 218443859; email: spg@lnec.pt; web: www.spgeotecnia.pt/cptuneis

3-6 JUNE
International No-Dig 2008 Moscow, Russia
Hosted by the International Society for Trenchless Technology and co-hosted with the Russian Society for Trenchless Technology, this will be the first ISTT event to be held in Russia. Contact: ISTT; Tel: +44 20 7259 6755; email: info@istt.co.uk; Web: www.istt.com

7-11 JUNE
North American Tunneling Conference San Francisco, USA
The 2008 NAT Conference will be held at the Hyatt Regency, San Francisco. Conference programme and registration details are now available on the UCA of SME web site. Contact: Society for Mining, Metallurgy and Exploration (SME); www.smenet.org

10-12 JUNE
Swiss Tunnel Congress 2008 Luzern, Switzerland
The annual review organised by the Swiss Tunnelling Society includes a lecture on grouting as a support measure during excavation, and an excursion to the Gotthard Tunnel. Contact: Thomi Bräm: Tel: +44 56 2002333; email: sia-fgu@swisstunnel.ch; web: www.swisstunnel.ch

23-25 JUNE
2nd Brazilian Congress of Tunnels and Underground Structures, Sao Paulo
With a host of metro, water, and hydropwer tunnels underway in South America, this conference will cover 17 tunnelling themes and focus on recent works in the area and will take place at the Centro Fecomercio de Eventos, Sao Paulo. Contact: Tel: +55 11 3522 8164; email: 2cbt@acquacon.com.br

25-27 AUGUST
Wireless Communication in Underground & Confined Areas Québec, Canada
The second international conference focusing on original research, innovative applications, or analysis of experiments on site, relating to the niche market of telecommunications in an underground environment (tunnels, metros, mines, etc). Contact: web: www.icwcuca.ca

10-12 SEPTEMBER
12th International Conference "Geotechnica 2008 - Geotechnics, Slovak Republic
The conference organised by the Technical Universities of Ostrava (CZ), Kosice (SK), and Gliwice (PL) focuses on techniques, technologies and monitoring of geotechnical construction. Contact: Nora Badíková. Tel: +421 (0)2 659 36 486; email: orgware@mail.t-com.sk

22-27 SEPTEMBER
2008 ITA World Tunnel Congress Agra, India
The 34th ITA General Assembly and Congress will be held at the Hotel Jaypee Palace, in Agra, India. In view of the large scale tunnelling works to be undertaken in the near future in India, there is much scope for agencies within as well as outside the country, to demonstrate their capabilities and network in a truly international gathering. Contact: CBIP; email: sunil@cpib.org; web: www.wtc2008.org

23-26 SEPTEMBER
InnoTrans 2008 Berlin, Germany
This international convention and trade fair for transport technology, including railway infrastructure, interiors, public transport and tunnel construction. The conference has become an increasingly popular addition to the event calendar. Contact: Messe Berlin; Web: www.innotrans.com

6-8 OCTOBER
International Congress 'Building Underground for the future,' Monaco
Organised by the Association Francais des Tunnels et de l'Espace Souterrain (AFTES), the three day event will consider the future use of the underground space with papers presented from all walks of the tunnelling spectrum. Contact: AFTES: email: aftes@snc.fr; web; www.aftes.asso.fr

22-24 OCTOBER
Underground Infrastructure of Urban Areas, Wroclaw, Poland
The conference is organised by the Urban Engineering division of the Institute of Civil Engineering, Wroclaw University of Technology, in association with the ITA, ISTT and EFUC (European Forum on Underground Construction). Contact: tel: +48 71 320 2914; email: andrzej.kolonko@ pwr.wroc.pl; web: www.bliw.wroc.pl/uiua/2008

BRITISH TUNNELLING SOCIETY

15 MAY: **Annual General Meeting followed by "The Arrowhead Tunnel"**
Rock tunnelling in challenging conditions with high water inflows. Presented by Brian Fulcher of J F Shea, and Mike Bell of Hatch Mott MacDonald. 6pm start, at the ICE, Westminster, London.

19 JUNE: **TUNNEL OPERATIONS**
Fire Life Safety. Speakers to be announced. 6pm start, at the ICE, Westminster, London.

27-28 OCTOBER
20th National Conference, Tunnelling Technology & The Environment, Ontario, Canada
Organised by TAC, the Tunnelling association of Canada. Contact: +1 604 629 1736; email: info@tunnelcanada.ca; Web: www.tunnelcanada.ca

10-12 NOVEMBER
ICDE 2008, Challenges and Risk Management of Underground Construction, Singapore
The International Conference on Deep Excavations (ICDE) is an ITA sponsored event organised by TUCSS. It aims to be a forum for contractors, engineers and owners to share and discuss experience. Contact: TUCSS; email: info@tucss.org.sg

23-28 MAY 2009
2009 ITA World Tunnel Congress Budapest, Hungary
The 35th ITA General Assembly and Congress will be held in Budapest. With a large amount of tunnelling underway and in planning, the organisers are confident it will be a successful event. Contact: Diamond Congress; email: secretariat@ wtc2009.org; web: ww.wtc2009.org

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Tris Thomas, 'Tunnels & Tunnelling International', Wilmington House, Maidstone Road, Sidcup, Kent DA14 5HZ, United Kingdom. Fax: +44 208 269 7840 Email: tthomas@wilmington.co.uk Web: www.tunnelsonline.info

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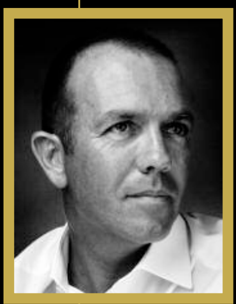

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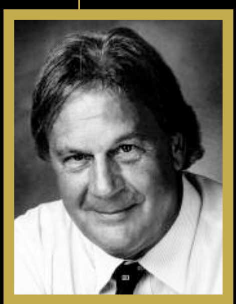

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