INTERNATIONAL EDITION
October 2013

Tunnels AND TUNNELLING

HEAVY METAL

Central Nippon Expressway Company assesses countermeasures for heavy metal contaminated spoil

North Asia • Roadheaders • Polish Investment

LONDON SWINGS

TUNNELLERS ARE coming to London this autumn. The excitement of major tunnel projects in the city has caught the attention of conference organisers and the speculation of further major projects in and around London is making the rest of the world take note.

Three conferences are taking place in London. As *Tunnels* goes to press the International Urban Tunnelling Conference is already underway.

Later this month the BTS is holding a two-day event in Westminster. And next month New Civil Engineer is hosting its Tunnelling 2013 conference near Tower Bridge.

SO WHY ALL THE HUBBUB?

London is home to Europe's largest infrastructure project, the 42km Crossrail metro project. At a budgeted GBP 14bn (USD 22.5bn), and coupled with the massive upgrades to the tube network's existing stations, which have been estimated to total a similar cost figure the project is keeping a lot of Europe's tunnellers busy for the next few years.

In the east of London the mega sewer, the Lee Tunnel, has been challenging shaft sinkers and tunnel builders alike. The GBP 635M (USD 980M) project runs for around 7km with shafts up to 87m deep.

But it is not the current workload that is drawing the crowd. London and wider England has major works in the pipeline too.

A second Crossrail project is under discussion having been our for public consultation this summer. The north-south line is estimated to cost GBP 10-15bn (USD 16-24bn).

The country also has plans for a second high speed line. HS2 will run from London to Birmingham, and as discussions progress, more and more of the line is being put in tunnel. Current cost estimate for the 225km project exceed GBP 40bn (USD 64bn).

Another major development to London's sewer network is planned with a 25km, 7m-diameter tunnel planned to run lengthwise under the Thames from Hammersmith in the West to Beckton Sewer Works in the East.

The three Thames Tideway main construction contracts are estimated to be worth in the region of GBP 1.6bn (USD 2.4bn) in total.

And on the smaller side, the planned Northern Line extension to Battersea is progressing. The approximately 3km-long, GBP 1bn (USD 1.6bn) project will connect with the Charing Cross branch of the Northern Line at the Kennington Loop.

This steady workload for the next decade or more makes London an attractive city for tunnellers.

We as an industry need to make sure that we demonstrate out ability to deliver projects on time, within budget and without incident so that the politicians and the public have the confidence in us to deliver future infrastructure projects.

These conferences will offer a platform for sharing what had been learnt on recent jobs and what might be expected on the upcoming works.

But they should also be used as a soapbox for promoting the industry to the clients and wider press that may be in attendance

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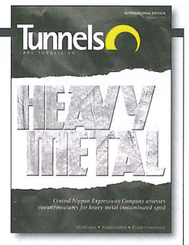
What do you think? Send your views to the editor and join the debate

Jon Young
Editor

Cover
Heavy metals in excavated spoil were far more prevalent than expected for the Nippon Expressway Co



Next issue
The next issue of *Tunnels* takes a look at our sister industry, the world of mining. Technical features on mine development and the requirements for excavation are presented with some interesting case reports from site. In addition, a focus on the economic trials of western Europe

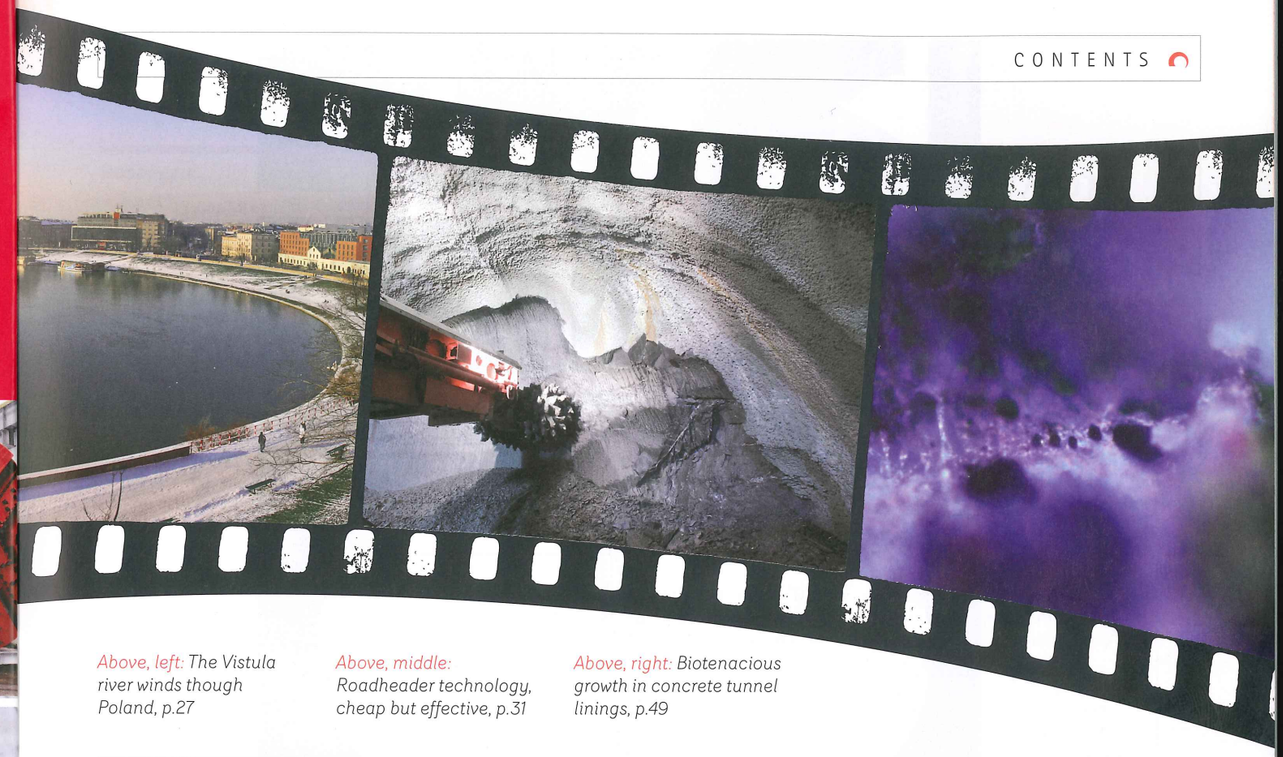
This month...

10 YEARS AGO

Tunnel boring machines could be used instead of cut and cover construction to build USD 1.3bn 4.5km long Kowloon southern link, planned by Hong Kong's Kowloon-Canton Railway Corporation KCRC. This follows concern by local legislators that building tunnels using cut and cover techniques would cause too much disruption, noise and dust in the heart of the Tsim Sha Tsui tourist district. KCRC East Rail extensions director Lee Kang-kuen confirmed that the TBM option was back on the table after apparently being discarded as being too expensive during a briefing to legislators in July. He believed that KCRC could decide which method was preferred by the end of this month.
Tunnels and Tunnelling, October 2003, p.7

20 YEARS AGO

Editor Peter Darling writes of the newly signed peace treaty between Israel and the Palestine Liberation Organisation. It might be said that the Israelis and Palestinians have at last come to terms with reality, and that with mutual recognition, peace will begin to spread through the region. For construction, pressure from the US Government has resulted in the Gulf States agreeing to underwrite some of the reconstruction costs, amounting to some USD 3bn. The European Commission is reported to be putting together a USD 575M aid package for the West Bank and Gaza Strip. The regions scars could be healed by real commitment, backed by hard cash.
Tunnels and Tunnelling, October 1993, p.5



Above, left: The Vistula river winds though Poland, p.27

Above, middle: Roadheader technology, cheap but effective, p.31

Above, right: Biotenacious growth in concrete tunnel linings, p.49

Contributors

Jaroslaw Adamowski

Jaroslaw Adamowski is a technical journalist who writes his debut article for *Tunnels* this month. Covering the potential impact of several large investment schemes in Poland, he interviews high ranking government and client side figures for his analysis on p.27. Jaroslaw comes from a background of writing for leading publications such as the UK's Guardian and Businessweek

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Bosphorus TBM en route

Turkey A 13.6m Mixshield from Herrenknect was completed early last month in Schwanau and is now on its way to the Bosporus jobsite in Turkey, Herrenknect announced recently.

The route of the project runs around 100m below sea level at its deepest point. The internal diameter of the tunnel will be 12m so that two lanes in each direction can be accommodated. They will extend one above the other on two levels. Some 3.34km of the tunnel with a total length of 5.4km are being created by a Herrenknecht TBM that will begin its underground mission from a launch shaft on the Asian side.

"The project is certainly one of the most challenging tunnelling operations currently being addressed in the world." said Georg Schleer, project manager, Herrenknecht.

Extensive geological and hydrogeological preliminary investigations showed that the tunnel builders must reckon with water pressures of up to 12 bar. Schleer added: "The machine's engineering presented us with a real challenge. Even if the pressure is extremely high up front at the tunnel face, the client must be able to change the cutting tools quickly and safely if necessary."

All London Tube ticket offices to close within two years, union claims

Great Britain All 268 Tube ticket offices could be closed under plans drawn up by a Transport for London (TFL) 'hit squad', the Transport Salaried Staffs Association (TSSA) has warned. TSSA said up to 6,000 rail and Tube jobs could be axed over the next six years.

The first 2,000 could go by 2015 with Tube ticket offices replaced by 'travel centres', mainly at major stations such as Waterloo and Euston, the union said.

"Boris had better rethink if he thinks he can sacrifice six thousand Londoners' jobs on his Long March to Downing Street," said Manuel Cortes, leader of the TSSA rail union. "We have a deal with TfL, which clearly rules out compulsory redundancies. If he tears that up, all bets are off."

SINGAPORE STATION AWARD

Singapore The Land Transport Authority (LTA) has awarded Contract T205 for the construction of Woodlands South station, on the 30km long fully underground Thomson Line, to Woh Hup (Private) Limited for a contract sum of approximately SGD 144M (USD 112M), the authority announced late last month.

Scheduled to complete in 2019, Woodlands South station is expected to improve the connectivity for residents in the Woodlands South area, as well as students from the Singapore Sports School, Christ Church and Woodgrove Secondary Schools. Construction works are expected to start later this year.

When completed, commuters heading to Gardens by the Bay will save 25 minutes on their journey as their direct train ride will take only 45 minutes.

The Thomson Line will enhance rail connectivity in the north-south corridors to the Central Business District and developments in the Marina Bay area.

Fully underground, Thomson Line comprises 22 stations, including six interchange stations: Woodlands, Caldecott, Stevens, Orchard, Outram Park and Marina Bay.

ADS announces JV with BaySaver

USA Advanced Drainage Systems, Inc. (ADS) acquired a controlling interest in a new joint venture established with BaySaver Technologies, Inc., the companies announced July 17. Called BaySaver LLC, the new company will continue to be based in Mount Airy, Maryland, and will focus on storm water filtration and separation technologies.

In 2008, ADS and BaySaver announced an exclusive marketing agreement for ADS to sell the Bay Separator and BayFilter units, which separate and filter pollution from storm water runoff. Manufacturing operations will be expanded nationwide. Currently, ADS has 56 domestic and international manufacturing plants and 28 distribution centers.

"We are very pleased to now completely include BaySaver in the ADS family," said ADS Chairman and CEO Joe Chlapaty. "During the past several years both companies have proven how successful these storm water quality treatment systems can be."

Ron Vitarelli, vice president of storm and sanitary markets for ADS said, "Evolving requirements imposed on municipal storm water systems by the EPA have created the need for a more complete storm water treatment methodology. As a solutions-based manufacturer we are asked to provide a 'treatment train' approach to owners and specifiers. The BaySaver product line rounds out the ADS storm water product offering."

To provide a better understanding of these requirements and how BaySaver filters and separators and other ADS products can build storm water systems to meet those EPA requirements, the ADS technical team will be conducting educational seminars, which can be arranged free of charge.

Japanese firm mulls metro project in Vietnam

Vietnam Japan's Marubeni will conduct a pre-feasibility study of the metro system project in Da Nang, a city in central Vietnam, according to the director of the city's Investment Promotion Centre Lam Quang Minh.

Minh said the Japanese company paid attention to the project during an investment promotion conference in Japan.

The central city plans to build the metro system in 2030, which would help connect the south of the city to its downtown area.

Evidence of 9,000 year old London settlement discovere

Great Britain Evidence of humans living on the Thames 9,000 years ago have been discovered by Crossrail archaeologists, the company announced earlier today. The discovery of a Mesolithic Œtool-making factory[1], which included 150 pieces of flint, among them blades, were found at Crossrail[1]s tunnelling worksite in North Woolwich.

Archaeologists believe prehistoric Londoners were using the site to test, divide and prepare river cobbles used to make flint tools, before transporting them to another site to complete the tool-making process.

Crossrail Lead Archaeologist Jay Carver said: "This is a unique and exciting find that reveals evidence of humans returning to England and in particular the Thames Valley after a long hiatus during the Ice Age. It is one of a handful of archaeology sites uncovered that confirms humans lived in the Thames Valley at this time.

THAMES WATER PLANS ONE-OFF 'SUPER-SEWER' CHARGE

Great Britain Bill payers have been warned they face one-off surcharges as well as annual hikes to their water rates in order to fund the Thames Tideway Tunnel, a major new sewer that aims to help tackle the problem of overflows from the London's Victorian sewers. Around 14 million people in London and the south face an extra GBP 29 (USD 45) charge on their water bills to help pay for the sewer. The company cites the costs of land acquisition for the Thames Tideway Tunnel as well as other preparatory work required for the construction of the tunnel, as its reasons for submitted an application to the industry regulator, Ofwat, to hit customers with the one-off charge. Stuart Siddall, CFO for Thames Water, said: "Ofwat resets price limits for each water company every five years, most recently in 2009, based on the best information available at the time. Then, during the five year period, almost all changes to costs and revenues, whether upwards or downwards, are up to us to manage. These include the costs of dealing with severe weather, changes to financing, employment, energy and chemical costs, business rates and tax.

"However, at the beginning of a five year period there are always a small number of potentially significant costs and revenues that can be clearly identified but not quantified. These are set out at the time of the price review and either the company or Ofwat can seek an adjustment, upwards or downwards, once the actual costs and revenues are known. That is what we are doing now."

Construction on the tunnel is due to start in 2015 and will involve 24 construction sites across London. Work will be split geographically into three main works construction contracts worth a total of around GBP 1.6bn (USD 2.4bn).

Rigs bound for Turkish HSR project

Turkey Senbay-Özgün JV, a part of Bayburt Group of companies, recently purchased seven Sandvik tunnelling jumbos for Istanbul – Ankara high speed rail relocation project called Dogançay. The project includes 10km of tunnel, Sandvik announced today.

Turkish state railway awarded the Dogançay project to the main contractor Senbay-Özgün on 10 May earlier this year. Bayburt Group purchased seven Sandvik underground drill rigs for the project: five units of Sandvik DD321-40 and two Sandvik DT820s.

The excavation in the high speed railway project will be challenging due to fractured rock and weak types such as siltstone, clay stone and mudstone, Sandvik stated.

The project is set to be completed on 11 November.

Second World War tunnels discovered at Southend primary school

Great Britain A primary school in Boston Avenue, Southend, was once the site for a network of tunnels dating back to the Second World War, local press reported recently. Builders working at St Mary¹s Prittlewell CofE Primary School found the tunnels as they carried out excavations at the site to extend the school building.

The tunnels are 6ft (1.8m) wide, 9ft (2.7m) deep, and run as long as 40ft (12.1m) beyond where the new classroom is being constructed. They are made from reinforced concrete. The tunnels will be filled with concrete for the work to continue.

Dozens hospitalised by Norway tunnel fire

Norway More than 50 people were sent to hospital after a lorry caught fire in Norway's second longest tunnel on Monday 5 August, police told local press.

The 11.4km Gudvanga tunnel in western Norway, connects the village of Gudvangen by Nærøyfjord with the Undredalen valley.

By 1pm the fire service had extinguished the fire, 45 minutes after the police received the first reports that a truck was on fire. Every single person evacuated was taken on to the hospital, a police spokesman stated. The exact cause of the fire is unknown.

Foreign donors to fund HCM City Metro

Vietnam Foreign donors have agreed to contribute USD 1.1bn for the first stage of a project to build a 8.9-km section of Metro Line Five linking Saigon Bridge in Binh Thanh District to Bay Hien Intersection in Tan Binh District in Ho Chi Minh City.

The Ho Chi Minh City Management Authority for Urban Railways (MAUR) said the Asian Development Bank (ADB) will finance USD 500M, the European Investment Bank (EIB) USD 200M, and the Spanish Government USD 270M. The remaining will be financed by the Vietnamese Government's counter capital.

This is the third metro route in Ho Chi Minh City. The other two are Metro Line One running from Ben Thanh Market in District One to Suoi Tien Tourist Park in Thu Duc District and Metro Line Two which links Thu Thiem New Urban Area in District Two to An Suong Bus Station in District 12.

Construction of Metro Line Five is scheduled to start in 2015 to link the Metro Line One (construction of which began in 2012) and Metro Line Two (construction to start next year).

Underground parking planned for Qatar tourist site

Qatar A massive and multi-layer underground parking facility is planned near Souq Waqif to enable visitors get easier access to the country's tourist hotspot.

Plans are also in place to expand the existing roads around the souq (market) to make sure the traffic flow is smooth when visitors pour into the hotspot.

The multi-storey underground parking facility planned at stone's throw from Souq Waqif would be able to accommodate as many as 2,000 cars at a time.

The facility is to be built beneath the expansive ground overlooking the picturesque necklace along the Gulf waters on the Corniche.

This is where the headquarters of Capital Police once stood. There already is one underground parking facility across Souq Waqif near Emiri Diwan, which can accommodate 750 cars at a time.

There is a subway that links the facility to the souq.

The new underground parking facility will have several subways leading to the souq.

BILLY BISHOP BREAKS THROUGH

Canada The core of the pedestrian tunnel to Billy Bishop Toronto City Airport is now fully excavated, with tunnelling equipment having broken through to the island-side on August 23, the Toronto Port Authority (TPA) announced.

Excavation of the main pedestrian tunnel began in June with the creation of two 6ft (1.8m) tunnels mined by TBM. Work on the seven small "crown" shafts, two of which host new City of Toronto water and sewer mains, began in December 2012. The project's next phase is the construction of the pedestrian tunnel skeleton, with completion of this element expected at the end of the year.

"I simply cannot say enough in congratulating a committed team that worked so diligently to get this tunnel in place," said tunnelling contractor Technicore's CEO Tony DiMillo. "Our in-house designed and built TBMs performed flawlessly, with some very innovative concrete design and placement techniques."

The pedestrian tunnel will connect the airport to the mainland where currently a ferry service transports passengers.

The project is being built through a public-private partnership model by Forum Infrastructure Partners (led by Forum Equity Partners with contractor PCL Constructors, facility manager Johnson Controls, lead designer Arup with ZAS Architects and Exp geotechnical engineers, Technicore Underground among others). The consortium is responsible for building, financing and operating the tunnel. The TPA retains ownership of the tunnel throughout the life of the P3 concession period.

When complete, the pedestrian tunnel will have four sidewalks moving at 2.3km per hour. From a bank of six elevators on the mainland side, passengers will go 100ft down to access the tunnel and travel 800ft underneath the Western Gap to escalators which take passengers to the airport's check-in area. The complete journey will take less than six minutes.

"The pedestrian tunnel is well on its way to being complete, now that the most technically difficult element of the project is behind us," said Toronto Port Authority Board Chairman, Mark McQueen.

Construction began on the tunnel project in March 2012 and completion is expected in the second half of 2014.

Plans in place to extend Dubai Metro

UAE On 5 September the Roads and Transport Authority (RTA) has finalised plans to extend the Dubai Metro Red Line from Rashidiya to Mirdif, to go with its earlier plan to extend the Green Line from Al Jaddaf to Academic City.

Both extensions are expected to be operational before 2020.

"As per the approved rail masterplan, there are two projects that are required to be ready before 2020, the Green Line extension from Creek Station in Al Jaddaf to Academic City and the Red Line extension from Rashidiya Metro station to Mirdif," said Abdullah Yousuf Al Ali, Acting CEO of the RTA's Rail Agency.

Although the areas both routes will cover have been decided, the exact routes and the number of stations will be planned next year, when work on the design of the projects will begin.

"The RTA is conducting more studies on the proposed extensions and the actual date to start work on the projects next year will be decided once the studies are complete. Irrespective of the start date, the projects will be in operation by 2020," he added.

The extensions are being planned bearing in mind the growing demand and popularity of the metro system as well as the continuous expansion of residential and industrial clusters across the length and breadth of Dubai. The plan also keeps in mind the growing population of the emirate which is estimated to cross the three million mark by 2020.

Both extensions are expected to add a substantial distance to the rail network, with the Green Line extending by up to 24 kilometres and the Red Line by around 12km.

The Red Line extension will serve booming new communities such as Shurooq and Ghuroob in Mirdif along with the adjoining neighbourhoods Al Mizhar and Al Warqa.

However, it is the Green Line extension that is likely to offer mass transit connectivity to large residential and industrial clusters as it will pass through Ras Al Khor Industrial Area, the heavily populated International City as well as residential and educational clusters such as Silicon Oasis and Academic City, serving a huge number of students.

The RTA's rail master plan also includes a rail network extension of up to 400km by 2030. It involves the proposed construction of at least four other lines.

The news of the expansion comes as Dubai Metro celebrates four years of its successful operations, with its popularity growing every day.

"Dubai Metro has seen around 20 per cent increase in ridership over the years with the current average daily ridership being 366,000. We have 58 trains operating together on both the lines, phenomenal growth in such a short period," said Al Ali.

Thai storm tunnel contracts inked

Thailand The Bangkok Metropolitan Administration (BMA) has signed THB 2.4bn in contracts for the building of a huge new drainage tunnel to help end flooding in six inner districts of Bangkok.

The contracts were awarded to Nawarat Patanakarn Plc, Thai Engineering Consultant and Consulting Engineering.

Bangkok Governor Sukhumbhand Paribatra said the Ratchada-Bang Sue tunnel would be large and would greatly improve drainage from low-lying areas where there is only limited capacity to release flood water into Chao Phraya River.

The flood tunnel would be built from Ratchadapisek Road to Lat Phrao canal, run along Bang Sue canal and meet the Chao Phraya River at Wat Kaew Fah in Kiak Kai area of Dusit district.

The 6.4km tunnel would have a width of five metres and be 20m underground. It would drain water from 56 square kilometres in six districts. It would also drain major roads including Phahon Yothin between Saphan Khawi to Lat Phrao junction, Vibhavidi Rangsit, Ratchadapisek, Samsen, Lat Phrao and Kamphaengphet.

Of the THB 2.4bn budget, 50 per cent would be supported by the government. There was also another THB 2.4M in consultancy fees.

Construction would take about three years, so the earliest it could be in use would be September 2016.

Sukhumbhand said the BMA had improved the drainage system in several areas, but improvements throughout the capital would be difficult time-consuming.

Two other large drainage tunnels are planned, a 9.4km tunnel in Nong Bon Pond for the east of Bangkok and a 13.5km tunnel on Prem Prachakorn canal for the east.

DETROIT-WINDSOR TUNNEL FILES FOR BANKRUPTCY

USA/Canada American Roads LLC, operator of the vehicle tunnel that links Detroit, Michigan, in the US, to Windsor, Ontario, in Canada, filed for bankruptcy on Thursday, July 25, citing reduced traffic.

The privately-owned firm filed for Chapter 11 bankruptcy protection in the Southern District of New York to restructure more than USD 830M in debt, according to court filings. In addition to the tunnel, the company owns and operates four facilities in Alabama.

Since debt refinancing in 2006, tolled traffic volumes have not grown enough to meet the 2006 projections, and in fact have experienced significant traffic declines. From 2007 through 2012, traffic has declined by between approximately 1.9 per cent and 8.6 per cent at each of the toll facilities. Traffic between Detroit and Windsor decreased at an average rate of 3.8 per cent a year.

Although Detroit's financial situation has contributed to the difficulties facing the debtors, American Roads said in court documents these Chapter 11 cases are not the result of the Chapter 9 bankruptcy filing by the City of Detroit a week previously. Though it does blame the city's decreased population.

Some 700,000 people live in Detroit currently, a sharp drop from its 1950s peak at 1.85 million. The city has some USD 18bn in long term debt. Reports of decay among residential areas, as well as commercial and industrial facilities across the city highlight the effects of this urban flight and diminished tax base.

The Detroit Windsor Tunnel (DWT) is a 5,160ft (1.57km) long tunnel beneath the Detroit River that has served as a border crossing since 1930. The DWT is jointly owned by the cities of Detroit and Windsor.

TBMs arrive in Brazil to deliver metro expansion

Brazil The first two TBMs have arrived in Fortaleza, marking a major breakthrough in the Brazilian market for the US-based company. Four 6.92m Robbins EPBMs have been ordered to construct Line 3 of the Fortaleza Metro.

Although the machines have been purchased, a contractor has yet to be named. The contracting tender opened in May 2013, and five contractors were invited to submit proposals. The machines are expected to begin boring in 2014 once a contractor has been announced.

Components from the US and Europe will be shipped to China where they will be assembled at Robbins' Pudong site.

Once the project commences, the machines will excavate sections of the Line 3 tunnel ranging from 4.3km to 5.8km long. The 12.4km long Line 3 will include 12 stations (11 of them running underground) from Chico da Silva to Edson Queiroz station within Fortaleza. The new line is part of a larger infrastructure development program for northeastern Brazil, one of the highest population growth areas in the country.

HK tunnel contract awarded

Hong Kong Sweett Group has secured a commission to provide cost management services for a 2km submerged cross harbour rail tunnel in Hong Kong, the company announced earlier this week.

As part of a team led by engineering firm Aecom, Sweett Group will provide cost management services for the fourth Cross Harbour Rail Tunnel, part of the Shatin to Central Link (SCL) railway. The contract includes cost planning, Bills of Quantities and tender cost estimates.

The project works include temporary reclamation, immersed tube tunnel under theVictoria Harbour, cut-and-cover tunnel, ventilation building, marine piling and the provisioning of a finger pier. The tunnel construction is scheduled for completion by 2020.

Kim Berry, managing director, Asia Pacific, for Sweett Group said: "We are delighted to have been appointed under the Consultancy Agreement on the fourth Cross Harbour Rail Tunnel. We have recently been particularly active in the Hong Kong rail sector, with current commissions on all four of MTR's main line extensions, an investment programme that will increase the network's length from just under 220km to over 270km during the next decade."

LTA re-awards DTL2 works following insolvency

Singapore The Singapore Land Transport Authority (LTA) has appointed McConnell Dowell South East Asia (SEA) Private Limited and SK E&C (Singapore) to complete construction works for three Downtown Line 2 (DTL2) stations following the insolvency of the earlier contractor Alpine Bau GmbH, which was awarded the contract for design and construction of the stations in September 2009, LTA announced recently.

McConnell Dowell (SEA) Private Limited will complete the construction of Sixth Avenue and King Albert Park stations and associated tunnels for a contract sum of approximately SGD 254M (USD 298.6M), while SK E&C (Singapore) will complete the construction of Tan Kah Kee station and associated tunnels for SGD 222M (USD 173.6M).

The two contractors were selected as they have the relevant technical expertise and resources to pick up quickly and commence completion works for the three stations, LTA said. LTA will work closely with the contractors to deploy more resources and manpower so that works can be expedited. With the expedited work schedule, DTL2 is expected to be completed by mid-2016.

Mr Chua Chong Kheng, deputy chief executive, LTA, said: "LTA's immediate priority is to start work as soon as possible now that the new contractors are onboard. There is about 50 per cent of works on station and tunnel construction to be completed. We will continue to explore areas where we can expedite works to speed up the construction without compromising on the safety. We seek the continued support of residents and stakeholders in mitigating the delay so that residents can enjoy the benefits of having a station at their doorsteps at the earliest possible."

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

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Share tracker

Company	July	August	Change (%)
Aecom (NYSE: ACM)	32.32	30.00	▼ 2.32 (7.18)
Atkins (LSE: ATK)	1,069.00	1,152.00	▲ 83.00 (7.76)
Balfour Beatty (LSE: BBY)	220.70	247.20	▲ 26.50 (12.01)
BASF Global (XETRA: BAS)	70.46	66.11	▼ 4.35 (6.17)
Bekaert (BSE: BEKB)	26.00	28.08	▲ 2.08 (8.00)
Bilfinger Berger (DUS: GBF)	74.23	74.30	▲ 0.07 (0.09)
Caterpillar (NYSE: CAT)	87.17	86.32	▼ 0.85 (0.98)
Costain Group (LSE: COST)	284.75	284.00	▼ 0.75 (0.26)
Ferrovial (MCE: FER)	12.64	13.31	▲ 0.67 (5.30)
Hindustan Construction Company (BOM: HCC)	10.10	10.65	▲ 0.55 (5.45)
Hochtief (XETRA: HOT)	53.50	57.67	▲ 4.17 (7.79)
Morgan Sindall (LSE: MGNS)	620.00	674.50	▲ 54.5 (8.79)
Sandvik (STO: SAND)	83.20	88.90	▲ 5.70 (6.85)
Shanghai Tunnel Engineering (SHA: 600820)	7.73	8.310	▲ 0.58 (7.50)
Strabag (LSE: STR)	16.06	17.23	▲ 1.17 (7.29)
URS Corporation (NYSE: URS)	47.94	47.67	▼ 0.27 (0.56)
Vinci (EPA: DG)	39.33	41.10	▲ 1.77 (4.50)

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

Central bank rates

	Rate (%)
AUD	2.50
BRL	9.00
CAD	1.00
CHF	0.25
CNY	6.00
EUR	0.75
GBP	0.50
INR	7.50
JPY	0.10
NZD	2.50
USD	0.25

Rates are taken on the 12th of each month.

CBE takes top segment spot in China

China Some 60 per cent of the current subway construction sites in China are using CBE segment moulds, the company claimed last month. Among the 18 Chinese cities where CBE Group is present are Shanghai, Beijing, Shenzhen, Wuhan and Xi'an.

HNTB made new ACUUS secretary general

USA Chief tunnelling engineer for HNTB Corporation, Sanja Zlatanic, has been named secretary general of Associated research Centres for Urban Underground Space (ACUUS), a North American, non-governmental organisation dedicated to partnerships among experts who design, analyse and decide upon the use of cities underground spaces. Zlatanic's term runs 2013 through 2017.

Zlatanic, a vice president based in HNTB's New York City office, has 25 years of experience with tunnels and complex underground structures.

She has been in a leadership role for many large transportation projects in the US and internationally, including the New York metropolitan area's Trans-Hudson Express Tunnel project, No 7 Subway Line Extension project, East Side Access project, Hudson-Bergen Light Rail Transit System and 63rd Street Line Connection.

"Through her active role in promoting sustainable underground space use, Sanja is respected among industry colleagues and project owners around the globe, as evidenced by her ACUUS board position and appointment to secretary general," said Nasri Munfah, HNTB chairman tunnel practice. "She is well-known for successfully leading complex projects."

Dhaka consultant awaits JICA approval

Bangladesh Prime Minister Sheikh Hasina will lay the foundation stone of the Metro Rail project in Dhaka soon as the funding agency, the Japan International Cooperation Agency (JICA), has given its consent for appointing a consultant.

"The project has moved a step forward with the clearance given for the appointment of consultant," communications minister Obaidul Quader announced in a statement last month.

Quader added, "The government signed a deal with JICA worth BDT 220bn (USD 2.8bn) for implementation of Metro Rail project on 20 February."

According to the deal, the JICA will provide a loan of BDT 9.24bn (USD 119M) for the appointment of consultant for the 20.1km-long Dhaka MRT development project.

Of the total cost of BDT 220bn (USD 2.84bn), JICA will provide BDT 165.95bn (USD 2.1bn), while the government of Bangladesh will arrange the remaining funding.

The Line Six MRT project will run from Uttara Third Phase to Bangladesh Bank.

Oil price

109.0 July 2013

109.3 August 2013

Values are taken on 12th of each month.

RAINDROPS KEEP FALLING ON MY HEAD

Dear Sir,
Regarding Andy Evans's article 'Wider View' in the fire protection section of Tunnels July 2013 (p.37).

While I generally agree with Mr. Evans position, the statement about water mist using less than standard drop sprays is physically incorrect. Water interacts with fire by preventing vaporisation at the fuel surface. In fact, it has been shown both in modelling and testing that larger standard drops do this better. The myth of less water with mist occurs because mist systems performance test and standard drop systems use prescriptive charts. I wrote a paper on this at the Fourth ISTSS in 2010 and Magnus Arvidson published results of a test program that qualitatively showed the same. If you have any questions, please let me know.

Kenneth Harris
Parsons Brinckerhoff

IN RESPONSE...

I find Mr. Harris's comments really interesting and it raises an interesting issue for tunnel operators – i.e. what water application rate should be applied to a tunnel fire, should a tunnel operator have control over the application rate for different fires and if so who decides and what are the decision criteria?

In his ISTSS 2010 paper, Harris reports that his computer simulations show that Fire Point theory indicates that the deluge rate actually necessary to control a fire is considerably less than the rates generally prescribed. Tunnel operators know that tunnel fires come in all shapes and sizes, from relatively minor car fires through to fully engulfed flammable fuel tanker fires. A tunnel active fire suppression (AFS) system needs to be able to cope with a broad range of operational conditions. The design criteria for any particular AFS (or fixed fire fighting system – FFFS) must specify the discharge rate, if my understanding is correct, Harris's work indicates that these rates could be considerably reduced whilst still providing benefit.

The Singapore LTA undertook some interesting test fire work in Spain during 2012. The test fires I'm referring to comprised stacked 20 per cent plastic pallets and 80 per cent wooden pallets to simulate a HGV load. The suppression rate was 12mm / min and the unsuppressed fire Heat Release Rate (HRR) was approximately 150MW. A finding was that the actual suppressed fire HRR depended upon the delay in operating the AFS. If the AFS was operated about four minutes after ignition, the fire HRR was controlled to between 18 per cent and 29 per cent of its uncontrolled potential. If the AFS was operated eight minutes after ignition the fire reached and maintained 65 per cent of its unsuppressed potential.

The practical reality for a tunnel operator when presented with a fire is that the AFS is very likely going to be operated at maximum deluge rate as quickly as possible – if they don't do that and a person is injured or considerable damage occurs to the tunnel then the tunnel operator is going to have to answer a lot of very uncomfortable questions and possibly be faced with insurers walking away. My feeling is that activating such a system over 75m to 90m for a car fire is more than a little excessive – we should have shorter discharge zones and the ability to control which ones are operated. Controlling the discharge rate within the activation zone is another issue entirely.

I don't profess to be an authority on Active Fire Protection system design – my article offered a Tunnel Operators view on some of the benefits and implications of system ownership. The particular reference to water usage rates I used does indeed come from the prescriptive charts and is extracted from reports and advice presented to tunnel operators by AFS consultants and designers – this will continue to be the case until the prescriptive charts are updated. AFS consultants and designers will continue to use the same prescriptive charts because if they find themselves in Court they have a defence of having designed to the prevailing codes and discharge rates. If the logical conclusion of Ken (and Magnus Arvidson's) work is that the prescriptive charts should be updated and design discharge rates reduced then great – smaller tanks, smaller pumps and a cheaper install.

Andy Evans
Road Tunnel Operator Association

News briefs

ITALY

Assembly of the TBM is underway on the site of La Maddalena in Val di Susa, Italy. Excavation of the first 200m of the 7.5km-long survey tunnel of La Maddalena in Chiomonte started at the end of 2012 using a mechanical shovel and hydraulic rock breaker. The remaining 7,300m will be driven by the TBM, which is nearly 240m-long and has is 6.3m in diameter.

SPAIN

The Board of Ministers authorised additional work for the Almunecar (Taramay) - Salobrena (Lobres) section on the motorway A7, in Granada, with an estimated value of EUR 30.12M (USD 40.23M). Work includes the completion of excavation on the La Minilla tunnel, with bore lengths of 2,000m and 1,993m, its waterproofing along the entire length, a bolstering of the drainage system for the ground-water filtration, the provision of new equipment and the tunnel power supply line. The construction contract has been awarded to FCC.

NETHERLANDS

The 11.34m-diameter Herrenknecht TBM nicknamed 'Boorbara' began excavation of the south tube of Skuiskil tunnel under the Ghent-Terneuzen Canal last month. Excavation of the north tube, which started on 27 January ended in mid-May. In October 2010, the contract for the construction of the Sluiskil Tunnel, with a bore length of 1,330m, of which 1,145m was to be excavated by TBM technology, and of a new 6km-long section of N62 was awarded to the consortium of BAM Civil, Wayss & Freytag, and Mobilis, Croon. The twin-tube tunnel has two lanes in each direction. It reaches a maximum depth of 33m below sea level, and has a maximum gradient of 4.5 per cent. The diameter of the tunnel is 10m.

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BRAZILIAN BON VOYAGE

Four 6.92m Robbins EPBMs have been purchased by the Brazilian Government's Secretary of Infrastructure in the State of Ceara (SEINFRA) for Line Three of Fortaleza's underground transit system.

Although the machines have been purchased, a contractor has yet to be named. The contracting tender opened in May, and five contractors were invited to submit proposals: Acciona/Centenco; Construcap/Copasa; Mendes Junior/Isolux; Metrofor (consisting of Odebrecht and Andrade Gutierrez); and Mobilidade Urbana (consisting of Camargo Corrêa and Queiroz Galvão). The machines are anticipated to begin boring in 2014.

Core drills underneath the city verified that challenging geology should be expected, including abrasive basalt and silty sand below the water table at water pressures up to 2.5 bar. The four EPBMs are being assembled in Robbins' new factory in Pudong, China, and as of August, two of the machines are in the process of being transported to Brazil, while the remaining two machines are in the assembly and testing process

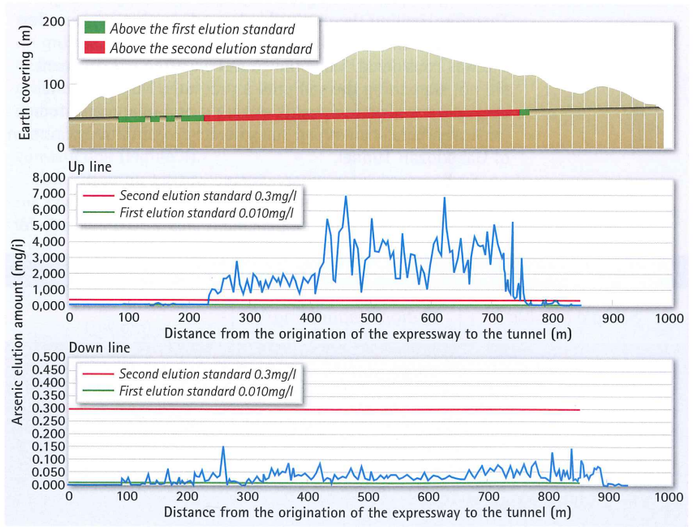
HEAVY METAL

The Central Nippon Expressway Company's Makoto Yamawaki, Masahiro Nakata, and Atsunori Ishida give *Tunnels* a preview of their assessments of countermeasures for excavated soil containing heavy metals at the Shin Tomei Expressway's Gakudozan Tunnel project. The final paper has been submitted for presentation at WTC 2014

GRANITE AND gneiss are widely distributed in the Aichi prefecture part of the Shin Tomei Expressway. Its 973m-long Gakudozan Tunnel and its surrounding ground is dominated by sandy gneiss and pelitic genesis. According to the pre-excavation survey, it was found that the gneiss-dominant area contained naturally-occurring heavy metals, including lead, cadmium, arsenic, and selenium. Since heavy metals can cause ill effects on human health, even if they are naturally occurring, they should be handled in accordance with the Soil Contamination Countermeasures Act (SCCA), which regulates environmental standards for handling of land with heavy metals in Japan.

The levels of heavy metals found in the gneiss were higher than the standards defined in the SCCA. It should be noted that although arsenic is not classified as a heavy metal, this article includes it in heavy metals since it is one of the hazardous substances.

Thus the tunnel was excavated along with the heavy metal survey. When excavated soil contained heavy metals, it was used for embankments within the main road of the expressway after necessary measures were taken. This article describes the plans for the pre-survey of heavy metal-containing soil and the testing method, its production situation during construction and responses during construction when the plan required changes.



Below: Figure 2, Longitudinal variation of arsenic elution amount

ORIGINAL PLAN

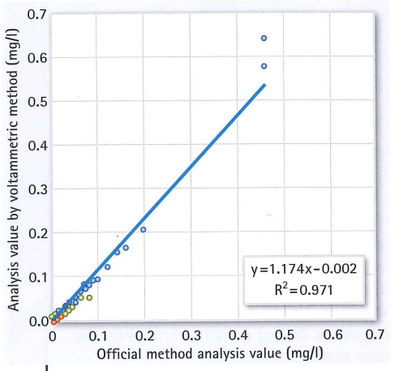
From the pre-survey, the amount of the tunnel-excavated soil that contains heavy metals and the amount that requires countermeasures were predicted, and the construction plan was made based on this.

Soil with arsenic that exceeded the Environmental Standards was expected from 3 per cent of the length of Gakudozan Tunnel and the adjacent Nukata Tunnel. The heavy metal-containing soil was planned to be contained within embankments of the expressway, after the measures that were specified in Japan's SCCA were taken. Due to the small amount of expected heavy metal-containing soil, anything that exceeded the environmental standards, and that would be produced prior to the completion of the embankment for heavy metals containment, was to be transported to paid concrete recycling facilities.

Survey method for heavy metals

Due to the necessity for making a tentative decision on the survey method of heavy metals in the soil before the test results were obtained, a test method that promptly provided results was desired. The voltammetric method was chosen after some consideration. To ensure the transparency of the adoption of this method, it was discussed with the environmental bureau, and then deliberated in a review session by a third-party.

In the environmental standards, the amount of heavy metals in soil and the elution amount, which represents the degree of elution in water, are specified. The heavy metal-containing soil in this area was a small amount, but was expected to exceed the environmental standards in terms of the elution amount. Four types of substances were expected in this area (i.e., lead, cadmium, arsenic and selenium), and



they were the subject of the survey. In order to judge the treatment necessity immediately after excavation, the survey frequency was set to once a day for total excavated soil, since blasting was used for tunnel excavation and all of the rock waste within the profile was mixed, and hence separation among lithological characters was not possible.

The specified test method in the Soil Contamination Countermeasures Act takes two weeks to get the elution amount test results. Therefore, the voltammetric method was used for testing elution amounts and contents immediately after excavation in order to obtain results faster. The voltammetric method is a qualitative and quantitative analysis of dissolved substances by the electric potential and electric current that are measured with the electrode submerged in the solution. This method enables results to be obtained in about 10 hours, and therefore it can reflect construction progress more effectively than the SCCA's specified method. In the course of adopting this official method, the standards for the voltammetric method were set based on correlation between the measured values of the SCCA's method and the voltammetric method for each substance. Figure 1 shows the relationship between the two methods, in terms of arsenic as an example. The correlation coefficient was high and had a sufficient correlation. The results and countermeasures were discussed in the aforementioned review session and it was confirmed that they were the proper method and countermeasures.

Although the voltammetric method provided results in a short period of time, a temporary storage yard with capacity for a one-day supply of tunnel rock waste was made for tentative storage at the construction site. A large tent was installed in the temporary storage yard to prevent the possible heavy metal elution from the tunnel rock waste in case of rain during temporary storage.

70%
Of the excavated length of the tunnel contained arsenic that exceeded the environmental standards

HEAVY METAL-CONTAINING SOIL PRODUCTION

In Gakudozan Tunnel, arsenic that exceeded the environmental standards was found in about 70 per cent of the excavated length, which greatly surpassed the original expectation. The maximum concentration was 6.90mg/l, while the elution standard in the Environmental Standards was 0.01mg/l. From the adjacent Nukata Tunnel (1,800m long), a high concentration of arsenic appeared. At the end, more than 400,000m3 of total heavy metal-containing soil was produced (70 per cent of excavated soil) from tunnel excavation for a total of two 'up' and two 'down' lines.

In Japan, a 30 times higher elution amount than the SCCA's environmental standards (arsenic : 0.01mg/l×30 : 0.3mg/l) is defined as the Second Elution Standards, and more strict countermeasures (more than two) are required. For this construction site, soil with a higher level than the environmental standards but with less than the Second Elution Standards was used as embankment material.

Figure 2 shows the tunnel length direction and the arsenic elution amount from the tunnel rock waste of 'up' and 'down' lines of Gakudozan Tunnel. Little arsenic elution was found at the location about 100m from the tunnel's mouth, but an arsenic level higher than the environmental standards was found in most of the deeper rocks. There was no trend in the detected arsenic elution amounts. For Gakudozan Tunnel, the arsenic elution amounts were completely different between the up and down lines that were only 30m apart. In both Gakudozan Tunnel and Nukata Tunnel, heavy metals that exceeded the environmental standards, other than arsenic, were not detected.

In order to handle the unexpectedly large amount of heavy metal-containing soil, a countermeasure to mainly contain heavy metals (the embankment) was adopted.

Due to the soil allocation scheme, Gakudozan Tunnel passage was needed in the early stages to use it for soil transportation. Excavations of both Gakudozan Tunnel and the adjacent Nukata Tunnel began at the same time.

However, unexpected amounts of heavy metal-containing soil were produced from both tunnels from the early stages when the preparation for embankments was not yet ready. Therefore, halting the originally planned, costly transportation of heavy metal-containing soil outside of the construction site was considered. Since the countermeasure embankment did not start using the soil until a year later, Nukata Tunnel excavation was paused and it was used as a temporary storage for heavy metal-containing soil in order to continue excavation of Gakudozan Tunnel.

Furthermore, a temporary storage was set up in the area near the tunnel where cutting was completed, during the period prior to when the embankment area would be ready for acceptance. The bottom of the temporary storage was paved with asphalt to provide a waterproofing layer, and the soil was covered with waterproof sheets during temporary storage.

As the heavy metal-containing soil increased, the embankment area to accept it became insufficient, and utilisation of mountainous narrow grounds as countermeasure embankment areas was discussed. Since the narrow grounds were sloped, a solidification and insolubilisation method was considered.

Prior to the countermeasure embankment construction, explanatory meetings were repeatedly held for a half year to obtain the consent of neighbourhood residents, who were concerned about health hazards. At the explanatory meetings, the following items were explained: the reasons for choosing the location of the countermeasure embankment, characteristics of heavy metals that would be buried, and the testing method for water quality in the surrounding area. In the end, with understanding and cooperation of the environmental bureau, the residents agreed with the conditions that the water quality survey in the surrounding area would be continued, even after the construction was completed.

Since heavy metal-containing soil production widely varies depending on location, it is important to perform detailed research and examinations in advance, and to make a plan based on the premise that the original expectation would be exceeded during construction.

Table 1. Arsenic elution amount and contents of sample

Sample number	Elution amount (mg/l)	Arsenic content (mg/kg)
Sample 1	Less than 0.001	Less than 5
Sample 2	0.013	Less than 5
Sample 3	0.37	10
Sample 4	1.7	180
Environmental standards	0.01	150

Source: Authors

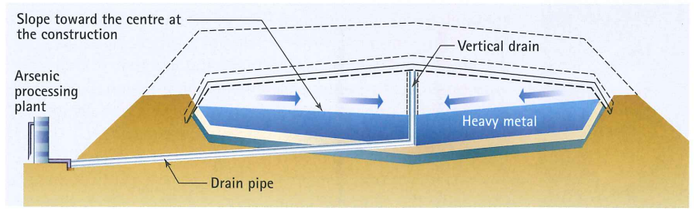
SEEPAGE CONTROL AND CONTAINMENT

The seepage control and containment method is a construction method to prevent heavy metal elution by blocking rainwater from heavy metals, using clay and liners with low water permeability. This method has the following advantages: the construction progresses at almost the same rate as the common embankment, once the bottom impermeable layer is built, and its maintenance is relatively easy since rainwater penetration is blocked when it is completed.

Overview of Seepage Control and Containment

Figure 3 shows the outline of the embankment structure. A double layer of impermeable synthetic rubber sheeting (t=1.5mm) with moderate elasticity was used as the top impermeable layer. The bottom impermeable layer consisted of a combination of a clay layer using bentonite mixed soil and a single layer of impermeable sheeting. To avoid effects on ground water as much as possible, the countermeasure embankment was planned at a higher level than the ground water level. Instead of temporarily covering the embankment with liners, a drain pipe was installed as a rainfall countermeasure during the heavy-metal embankment construction (Figure 4).

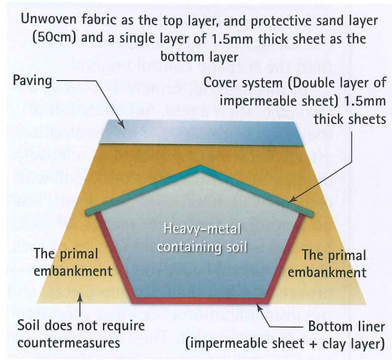
During construction, it promptly discharged rainwater out of the embankment that fell on the heavy metal-containing soil. When it rained, drainage water from this drainpipe was checked for arsenic elution. A neutralisation plant for arsenic was built next to the construction site, in case arsenic elution was found from drainage.



Opposite page: Figure 1, the relationship between elution amounts measured by the two methods

Right: Figure 3, Conceptual image of embankment by the seepage control and containment method

Below: Figure 4, Concept for the rainwater drainage system



Construction work

For the bottom impermeable layer, the bentonite mixed soil was installed and then impermeable sheets were placed. In a laboratory test, the bentonite mixed soil was first pretested for the relationship between the amounts of added bentonite and the dry density, to meet the specified hydraulic conductivity (K ⊠ 1×10-8m/s). Then the number of passes of compaction that provided the specified dry density was specified by a field trial. Wide impermeable sheets were used to reduce numbers required for adhesion at the construction site. Unwoven fabric and a protective sand layer (t=500mm) were used as protective materials for the impermeable sheet.

Since the tunnel rock waste was masses of rock, the embankment with the heavy metal-containing soil was built by the specified construction method where the adequate number of passes and the finish thickness of each layer were decided by testing. The official method analysis was conducted for every 900m3 of the countermeasure embankment with the heavy metal-containing soil, as specified in the SCCA, and the characteristics of the heavy metal-containing soil were monitored.

Once the heavy metal-containing soil was embanked to a predefined level, the upper impermeable layer was promptly constructed and the containment of the heavy metal-containing soil was completed. According to the after-mentioned water quality monitoring results, heavy metal elution due to rain did not occur.

SOLIDIFICATION AND INSOLUBILISATION METHOD

As the amount of heavy-metal containing soil largely increased, the countermeasure embankment was required even for narrow slopes. Countermeasures that used liners were not sufficient to maintain embankment

stability, so solidification and insolubilisation was considered rather than the seepage control method.

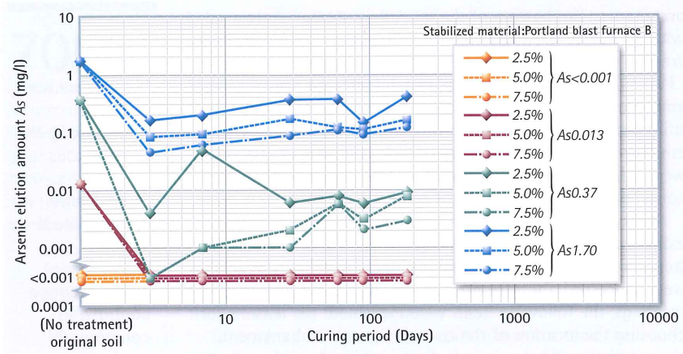
In this method, cement is used as an insolubilisation agent. Solidification of the cement provides the insolubilisation effect. There were examples of relatively small-scale constructions using soil with cement as an insolubilisation agent, but no precedent existed for masses of rock. Samples were taken from masses of rock that contained heavy metals that were broken into less than 100mm pieces, and the insolubilisation effect was checked by a laboratory test. They were then used for the expressway embankment and water quality was monitored.

CONFIRMATION TEST FOR SOLIDIFICATION AND INSOLUBILISATION

Effectiveness of the solidification and insolubilisation method using the Portland blast-furnace cement was verified first by a laboratory test. For this construction, arsenic was checked since it was the only heavy metal found from the tunnels.

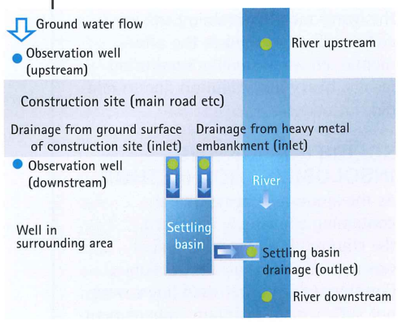
For the verification test, cement solidification test pieces were made with soil that had a higher arsenic level than the elution standards. The relationship between the curing period of the solidification test pieces and the arsenic elution amount was investigated. The test was conducted for four original soils with different arsenic elution levels, and the stabiliser additive rate was tested for three levels (Table 1).

Required test pieces were created using a 100mm mold. They were isothermally cured for the predetermined period in atmosphere at 20oC. After curing, the samples were broken into less than 2mm particle size and the official method analysis was conducted. Since the elution amount was steady for 60 days, and even for 180 days of curing, the construction method was determined based on these results. The test results are described in Figure 5. A verification test for long-term stability is not required by law, but a two-year ground water test is mandated.



Above: Figure 5, Relationship between curing period and arsenic elution amount

Below, left: Figure 6, Water quality monitoring plan



Long term stability of the solidified and insolubilised soil against pH changes

In order to examine the long-term stability, the solidification and insolubilisation effectiveness was tested in strong acid and alkaline conditions.

In general, it is said that there is a possibility of elution of heavy metals. when the insolubilised soil is exposed to acid or alkaline conditions. Causal factors include the oxidisation effect of sulfuric acid that is eluted from pyrite in heavy-metal containing soil, and pH changes due to exposure to an alkali.

As an evaluation of the long-term stability of the soil, which was solidified and insolubilized by cement, and of the stability of the insolubilisation technology, elution tests were conducted for the 60-day cured test pieces. For the test, sulfuric acid or lime hydrate was added. The test results are shown in Table 2.

For the original soil that had less than 0.013mg/l arsenic elution amount, re-elution of arsenic was not observed in acidic and alkaline conditions after solidification and insolubilisation, and therefore, they were stabilised.

For the sample with the elution amount of 1.70mg/l, the cement additive rate of 5 per cent decreased the elution amount less than 0.3mg/l, the Second Elution Standards. Thus, the cement additive rate was set to five per cent of the dry weight of the base material (100kg/m3) at this construction.

For the original soil sample with an arsenic elution amount of 0.37mg/l, 5 per cent cement addition lowered the arsenic elution amount to about 0.001mg/l, which was less than the elution amount standards for soil, 0.01mg/l. For the original soil sample with the arsenic elution amount of 1.7mg/l, 5 per cent cement addition lowered the arsenic elution amount to around 0.3mg/l, i.e., the Second Elution Standards.

The solidification and insolubilisation effect by cement was effective even after 180 days.

CONSTRUCTION OF THE SOLIDIFIED AND INSOLUBILISED EMBANKMENT

For the tunnel rock waste that was judged as heavy metal-containing soil, a screen mesh size of 40mm was used in the crushing machine. However, due to its flatness, actual maximum grain size was over 40mm and less than 100mm after crushing. To produce the embankment material, the grain size was adjusted, and then the soil was mixed with cement and water by the portable soil improvement machine.

The embankment material was handled as stabilised soil, and quality control standards were set according to company standards: the degree of compaction should be higher than 97 per cent in terms of density ratio. Testing frequency specified in the law is every 900m3 for countermeasure embankment. Arsenic elution was also checked at the final stage by the SCCA's Official method and the voltammetric method.

Due to the difficulty of sampling from the stabilised-cement embankment, samples were made with the embankment material from the construction site immediately after mixing. They were tested for the arsenic elution amount after seven days of curing.

As a result, the voltammetric method showed that arsenic elution amount was lower than the environmental standards. In addition, the arsenic elution amount measured by the SCCA's official method did not exceed the lower limit (0.001mg/l).

WATER QUALITY MONITORING

The construction within the office was undertaken according to the following plan, which included countermeasures for muddy water in addition to heavy metals.

- In order to prevent discharge of material to rivers during construction, rainwater in the all construction areas was directed to settling basins where fine-grain fractions were separated, and then water was discharged to rivers.
- For water quality monitoring during construction, turbidity, pH, and electrical conductivity were measured twice a day at the inlet of the settling basin, and the outlet to the rivers.
- Monthly water quality surveys (including heavy metals) were conducted both upstream and downstream of the sites
- In order to monitor the effects on ground water, observation wells were installed up and downstream of the embankment
- During the construction of the heavy-metal countermeasure embankment, arsenic concentration in drainage water was measured at the outlets of the drain pipes that discharged rainwater from the embankment.

RESULTS AND REMARKS

From the results of the water quality monitoring for the seepage control method, pH and arsenic concentration at each observation point and measurement did not exceed the environmental standards during and after the construction.

The results of the ground water quality monitoring for the solidification and insolubilization area also did not find any abnormal value in pH and arsenic concentration.

Drainage water from the solidified and insolubilised embankment was alkaline. This water was directed to the muddy water treatment plant, which was used at the time of tunnel excavation, and then discharged to rivers after the water pH was adjusted.

The risks of construction works that produce heavy metal-containing soil often appear unexpectedly.

Therefore, it is important to include the following: a detailed pre-study, a plan that takes into consideration the elution characteristics of heavy metals and testing methods learned from case studies, preparation of possible countermeasures for changes, and advance discussions with local communities and relevant ministries. Also, proper adoption of countermeasures for changes is important during construction

2
Year interval that ground water tests are required

References

[1] **Koichi Wazaki and Makoto Yamawaki**, *The Countermeasure Embankment and Construction using Gneiss that Contains Heavy Metals and Pyrite in Shin Tomei Expressway.* (Soils and Foundations 2012) 60-7: p10-13

[2] **Makoto Yamawaki, Masaki Nakano, and Nobuo Mishima**, *Countermeasures against embankment material with heavy metals in Shin-Tomei Expressway.* (Geology and Survey 2012) No. 135.

Table 2. Changes in arsenic elution amount in response to acid and alkali (60 days curing)

Sample case	Elution testing condition	Cement additive rate 2.5%	Cement additive rate 5%	Cement additive rate 7.5%
Case 1 0.001mg/l	After solidification and insolubilisation	Less than 0.001		
	Sulfuric acid environment			
	Lime hydrate environment			
Case 2 0.013mg/l	After solidification and insolubilisation	Less than 0.001		
	Sulfuric acid environment			
	Lime hydrate environment			
Case 3 0.37mg/l	After solidification and insolubilisation	0.008	0.006	0.006
	Sulfuric acid environment	0.009	0.007	0.007
	Lime hydrate environment	0.004	0.005	0.004
Case 4 1.7mg/l	After solidification and insolubilisation	0.37	0.12	0.11
	Sulfuric acid environment	0.41	0.14	0.12
	Lime hydrate environment	0.21	0.086	0.072

Source: Authors

The Polish government has announced plans to finance the drilling of the twin 2.06km-long tunnel in the Mały Lubon massif and the twin 2.27km-long tunnel in the Wałbrzyskie mountains. The investments are to be part of Poland's PLN 35.7bn (USD 11.07bn) road development plan for the years 2011 to 2015. **Jaroslaw Adamowski** reports on the latest boost to Polish tunnelling

RIVER WILD

IT IS estimated that two Polish tunnel projects will be worth about 25 per cent of the funds allocated for the massive National Road Development Programme (NRDP), which could represent as much as PLN 8.9bn (USD 2.76bn).

Under the plan, the tenders are to be launched by the end of this year, according to Polish Minister of Transport, Construction and Maritime Economy, Sławomir Nowak. While the launch of the tenders is scheduled for this year, the two investments are to be made between the years 2014 and 2020. ❱

Jaroslaw Adamowski
Jaroslaw writes his first article for *Tunnels* and looks at investment in tunnelling in Poland. He is a freelance journalist for leading titles

"This is a very significant moment for us. After...the decision by the Council of Ministers we are now starting to implement [these investments]," Nowak says, adding that the planned infrastructure investments are to be financed as part of the first round of funds allocated under the European Union's (EU) budget for the period between 2014 and 2020.

The twin tunnel to be excavated through the Mały Lubon massif, located in Poland's southern Tatry mountains, will be part of the S7 expressway. The 2.27km twin tunnel fitted with duplex motorways, which will pierce through the Wałbrzyskie massif, will be built on the 150km S3 expressway. The expressway will connect the Polish towns of Nowa Sól and Lubawka, and it will be constructed in proximity of Stare Bogaczowice town. The Wałbrzyskie mountains are part of Poland's south-western Sudetes mountains located in the Lower Silesia (Dolnoslaskie) region.

According to Urszula Nelken, the spokesperson for the General Directorate for National Roads and Motorways (GDDKiA), the project in the Wałbrzyskie Mountains will be NATM.

"In respect to the tunnel located on the S3 expressway, the project designer doesn't foresee any particular difficulties or technical challenges [for tunnel construction]," Nelken tells *Tunnels*. "In his view, NATM is the most suitable method which can be used in the conditions."

WORLD STAGE

Moreover, the latter expressway has key importance for Poland's participation in European joint road infrastructure projects. The S3's 150km part located in the Dolnoslaskie region is to become part of the international E65 route.

The second major tunnel project, located on the S7 expressway, will have a length of exactly 2,058m, according to information obtained from the GDDKiA. It is also to be fitted with duplex motorways. At its highest point, there will be 107m between the tunnel's bottom and the mountain's tip.

"Only 160m of the tunnel will be built using the cut and cover method, and the rest will be built using drill and blast," Nelken says, emphasising that "the final choice of the method will be made by the developer."

The S7 expressway also has an international dimension, which accounts for the importance assigned to it by the Polish government. The road is a trans-border route leading to Slovakia.

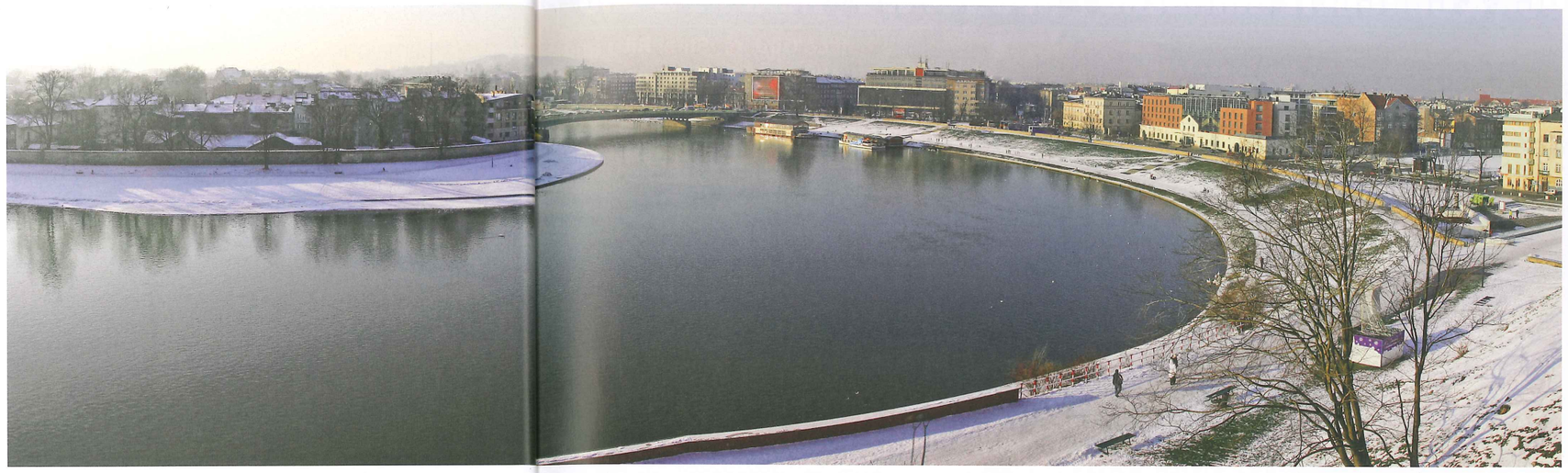
In regard to the tunnel specification, its central part will be fitted with cross passages every 172.5m, as well as an emergency ventilation system. The middle part of the tunnel will have an emergency lay-by in each of its tubes.

To provide sufficient and fresh air ventillation in the tunnel, the extraction system will be based on a channel with a capacity of some 18sq.m.

The tunnel investments in Poland's Lower Silesia and Małopolskie region are of key importance for the country's tunnelling industry, local observers say. Presently, the country's longest tunnel is located on the S69 expressway in the part that runs through Laliki municipality.

The 678m-long tunnel is less than 30 per cent of the length of the planned 2.27km tunnel in the Wałbrzyskie mountains. The Laliki tunnel was constructed by NATM.

Right: The Vistula River as it curves through Krakow



HIGH DEMAND FOR ROAD AND RAIL TUNNELS

An analysis by Krzysztof Bebek from Carbo Projekt, an architectural project company based in Tychy, Poland, outlines the technical aspects of the construction of the tunnel designed to pierce through the Mały Lubon massif, all the while pointing to the continuing rise in demand for new tunnels in Poland.

"Over the past few years, we have observed an increasing demand for road and rail tunnel infrastructure in Poland," Bebek says in the analysis. "[The country's] significant economic development in addition to the dynamic rise in road users has made the current infrastructure insufficient. This has been followed by the...rapid expansion of the transport infrastructure, adapted to local...conditions, a result of which include, amongst others, the road tunnels which have been constructed over the past few years."

SAFETY THRESHOLD

The analysis also points that, due to the fact that the European Commission's Directive 2004/54/EC on minimum safety requirements for tunnels in the Trans-European Road Network has not been fully implemented into the Polish legislation, "the existing rules and norms in many areas are not adapted to the specificity of tunnels, or even do not address certain issues related to [the construction of tunnels]." As a result, a number of technical aspects of the construction of the planned tunnel in the Mały Lubon massif will have to be a subject of a thorough technical debate, the analysis says.

TBM PROJECT IN GDANSK

Meanwhile, other major tunnels that are currently developed in Poland include the project currently being built in Gdansk, in Poland's northern Pomerania (Pomorskie) region.

The 1.4km-long Gdansk twin road tunnel is drilled under the Vistula river. Excavated by TBM, the investment is carried out by local municipal utility Gdanskie Inwestycje Komunalne (GIK), which handed the contract to Spain's construction and civil engineering business Obrascón Huarte Lain. Works on the Gdansk-based project were commenced started in late May. The latest investment is estimated to be worth about PLN 885M (USD 274.3M).

At its lowest point, the Gdansk tunnel will run 35m under water surface. It will be fitted with duplex motorways.

The 12.56m-diameter TBM used on the 1.4km project, dubbed the Damroka, has a 3.5MW capacity, a weight of 2,000t and a length of roughly 90m.

STRONG ECONOMIC POTENTIAL

Under the 2014-2020 EU structural funds perspective, Poland is to receive as much as EUR 21.53bn (USD 6.67bn) for modernising its infrastructure and protecting the environment. A large portion of these funds will be spent on construction of new roads and tunnels.

In addition to the funds for infrastructural investments that Poland secured from the EU, the country's economic climate will also be playing an important role in the potential development of its tunnelling industry. In spite of the ongoing financial turmoil in the Eurozone, Poland's economy has managed to stay afloat.

In 2011, the country reported GDP growth of some 4.5 per cent, compared with the Eurozone's mere 1.4 per cent, according to data published by Eurostat. Last year, Poland's GDP decreased 1.9 per cent, while the Eurozone's GDP contracted by 0.6 per cent.

For 2013, the Polish Ministry of Finance is projecting a GDP growth of about 2.2 per cent. If these predictions are confirmed, this could mean that the country's construction industry could be put back on track with the help of the flow of new funds from the EU.

6.67

The funding in USD billions that poland is set to receive in the 2014-2020 EU structural funds perspective for modernising its infrastructure

"In spite of the financial turmoil in the Eurozone, Poland has managed to stay afloat"

But analysts also point to some reasons for concern. In July, news broke that Poland's public deficit will be higher this year, triggering a series of cuts in the ministries' budgets.

However, due to the fact that the country's road infrastructure investments have secured major co-financing from the EU and are perceived as prioritary by the Polish government, it is unlikely that the two tunnel projects will be affected by the budget cuts, according to arguments by local observers.

CONSTRUCTION LAW TO BE REFORMED

The Polish government has also undertaken efforts to reform the country's legislation on construction projects, which could also have significance for the upcoming tunnel investments.

The reform aims to accelerate administrative procedures imposed on construction investments and decrease bureaucratic barriers.

Another objective was to introduce more transparency and accountability into these processes. The proposed changes into the construction law bill were passed by the Polish parliament in late July.

"The aim of these changes is to radically simplify the construction process which is currently viewed as overtly regulated and susceptible to rules that are often modified," the Ministry of Transport, Construction and Maritime Economy tells *Tunnels*

DOWN THE ROAD

Roadheaders, the underdog of the tunnelling industry, have secured their place as a economical and variable excavation tool, ideal for short drives and changing ground. Technical journalist **Rhian Owen** examines the principles

THE SIXTIES saw huge achievements in technology. Humanity entered the space age by putting a man on the moon. The computer mouse, the computer game, handheld calculator and the first cash point were all products of the decade. For the tunnelling industry, the late 1960s were the first time roadheaders appeared on tunnelling sites - having been developed initially for coal mining. While a comparatively small player in the tunnelling market when compared with rival equipment types such as TBMs, roadheaders have been responsible for excavating some of the most challenging tunnel lengths in fiercely varying geology.

Rhian Owen
As a journalist and technical writer Rhian began working with *Tunnels* in 2011

"Roadheaders were first introduced and developed for excavation of coal in Hungary in the 1950s," says Karl Mitterndorfer, president of machine manufacturer Antraquip. "But the Hungarians couldn't manufacture effective machines - it was a communist country then. "The machine became successful when the British and the company Voest Alpine of Austria, bought by Sandvik, started building the machines in the early 1960s." By the late 1970s roadheaders were widely used and accepted on tunnelling projects.

Above: A key strength of the roadheader is its off-the-shelf nature, allowing it to be ordered and delivered early in a project's lifetime

CUTTERHEAD CHOICE

The fundamental tool of any roadheader is the cutterhead. Two cutterhead types have been developed for roadheaders. The transversal-axial cutterhead rotates parallel with the boom, ripping the rock. The axial cutterhead rotates perpendicular to the boom and mills the rock.

There is much debate about when each cutterhead type should be used. Machine supplier Webster Machines argues "Between the two types of roadheader cutter heads, the ripping and the milling heads, the ripping type is more suitable for hard rock cutting. This is due to more efficient cutting during sumping, due to more efficient cleaning of the face, and because the picks attack the tunnel face perpendicularly and thus utilise the machine's total weight as reaction force to the pick's cutting force."

Antraquip's Mitterndorfer says: "If the face of the tunnel is hard to penetrate but there are some small softer openings or cracks it is definitely easier to do this with an longitudinal-axial head. If no such cracks are available and you have to go through a hard solid tunnel face, in our opinion, the transverse head is superior. Sometimes, the customer has a preference and we only recommend, but if the customer insists we will supply what they want."

35
The approximate strength of rock in MPa that early roadheaders were able to cut

210
The modern limits to rock cutting capability in MPa faced by roadheaders

On either type of head, an optimal design is necessary to match the rock cutting characteristics and maximise the production rates.

The design parameters include the spacing between picks, location of picks, their tilt angle and the skew angle.

Above: Rear view of an MT520 roadheader showing truck-loading conveyor

PUSH FOR HARD ROCK

Competition among the various excavation technologies is fierce. For a while some equipment and methods had a strong niche that only they served. But as technology has advanced the manufacturers have been pushing equipment into new territory. Roadheaders have traditionally operated in softer and friable rock, but in the fast 50 years the machines have developed greatly. Roadheaders have steadily increased in weight, size, and cutterhead power to tackle tougher rocks.

"The first roadheaders were very small," says Mitterndorfer. "They were 12t to 13t and had very little power. They were only able to cut rock with a strength of 5,000psi (35MPa). Now we are looking at 30,000psi (210MPa). The range went from 12t up to around 135t, which is what Sandvik is doing.

"Naturally, today everything is sturdier and the materials are better. Hydraulics are a completely different world to hydraulics 30 years ago. Electrics are completely different. You also have a computer in the machines and can run them remotely. It's safer now, certainly. There are a lot of differences."

The heavier machines and higher cutterhead torque apply a much greater force onto the rock face. But when facing very hard rock conditions, the equipment is still playing catch up with TBM technology.

"Hydraulics are a completely different world to hydraulics 30 years ago"

Sandvik's Wilhelm Papst, manager for sales support and mechanical cutting, says that there are still economic limits and it is not always best to use a roadheader for tunnelling.

"The TBM has its advantages over a roadheader," he says. "This is mainly the fact that you can cut very hard material. The roadheader is limited, machines can economically cut up to 80MPa. Our hard rock miners can cut up to 120 to 130MPa, but it depends on how the rock is fractured. If the rock is fairly fractured, you can cut even harder material, but if it is solid then we say 120MPa is the economic limit."

Mitterndorfer adds: "Indeed, a roadheader is limited by the hardness of the material. In addition, a TBM is justifiable if the tunnel's length is such that it pays to spend so much money - a TBM costs far more than a roadheader. If a tunnel is longer than two miles [3.2km], I normally put it aside and say it's a TBM job. However, to use a TBM in an application with many rock faults and where the material to cut changes quickly from soft to extremely hard or vice versa, can be extremely difficult. The danger is, the TBM can get stuck and cannot go forwards or backwards. Then you have a problem. It's a nightmare for every tunnelling engineer."

Mitterndorfer adds that this is the

"The quiet of the roadheader is helping it win back ground"

reason that the design engineers of the 18,660ft (5.6km) New Irvington Tunnel in California did not allow the use of a TBM. Southland/Tutor Perini JV is using two Antraquip roadheaders for the project as well as controlled detonations to excavate the two headings. Work has been challenging with high groundwater inflows and pressures, some squeezing ground areas and extensive pre-grouting.

GRITTED TEETH

The teeth of the roadheader have also developed to meet the challenges of tougher ground. According to Webster, picks are tipped with tungsten carbide and are available as radial 'flat' bits or rotating, conical 'point attack' bits. Most modern roadheaders use point attack bits. The general rule for carbide selection is: for hard-rock cutting, soft carbide is used because it does not shatter on impact. Soft rock is excavated with hard carbide, which has high wear resistance. Webster explains, "The spacing between picks must be optimised by analysing rock failure behaviour and anticipated depth of penetration. Also, cutter head layout must be balanced by controlling the placement of the cutters to create an even pick force distribution to minimise vibrations. This issue is of crucial importance since the increased spacing means less number of cutters and potentially higher vibrations. The head vibration can have adverse effects on the production rate, machine life, and maintenance. Consequently, an optimised cutter head design, achieved by well balanced pick distribution and minimised vibration, can enhance the performance of a given machine."

Pick wear is mainly influenced by the rock properties and the degree of mineral interlocking. Major manufacturers have proprietary empirical tables and graphs for pick consumption in rocks of various unconfined compressive strengths and content of abrasive minerals. Also, tables with production rates (m^3 per hour) are available for each cutter head power in rock and minerals of various UCS (MPa). If the roadheader utilisation rate as a percentage of the available face time (net cutting time) is known, relatively accurate pick cost and shift production rate estimates can be prepared.

BATTLE AGAINST BLASTING

Roadheaders are often pitched against drill and blast technology. The systems share the ability to respond to changing ground conditions. Blasting is typically more efficient in harder rock conditions. "Depending on the material," says Antraquip's Mitterndorfer, "if the rock is too hard for a roadheader or is just marginal for a roadheader then it might be more efficient to just drill and blast. Drill and blast technology has advanced too; in the early days, I remember 30 or 40 years ago, a tunnel that was excavated with drill and blast really looked bad - loads of over-excavation - but the technology improved substantially there."

However, the quiet of the roadheader is helping it win back ground. Sandvik's Papst says, "Sometimes you are simply not allowed to use explosives. Especially when excavating near historical buildings or through urban areas. Environmental reasons may also block the use of explosives. In these cases customers may use roadheaders even if it is more expensive."

Mitterndorfer adds, "In many situations in today's world you're not allowed to drill and blast or it is very difficult to do it. Following 11 September 2001, the US has become very restrictive on handling any explosives. Everyone needs to be certified. If you're in an explosive area, then there's a danger of explosives. So you need to have your electric system approved as necessary.

"You have to also meet the local standards, which are sometimes difficult"

Below: A Sandvik engineer oversees excavation

CABLE GUY

IT'S UNUSUAL for the disruption of a tunnel project to be welcomed by local residents, but in the Harlesden neighbourhood of northwest London, UK, this has been exactly the case. Landscaping works and the constant presence of site personnel have prevented the loitering and other activities that were causing problems for the neighbourhood's residents.

A new cable tunnel has gone seemingly without a hitch in the Willesden/Harlesden neighbourhoods of north London. **Alex Conacher** tours the site with Murphy's tunnelling project manager Keith Pollard

And it's a project by the client UK Power Networks (UKPN) that is to thank. The electricity network operator has set out to construct 1.4km of tunnels to house four 132kV cables between two substations in the Willesden and Brentfield Park neighbourhoods.

LOCATION, LOCATION

The Willesden reception shaft is located in an existing National Grid substation, while the main drive shaft is in Brentfield Park, a green field site close to substations at Leicester Road, Taylor's Lane and Gibbons Road, as well as E-ON's Leicester Road Power Station. A third, safety/ventilation shaft is located on the external perimeter of E-ON's site at Taylor's Lane. This will also be used to bring the product cable in.

"The location of the drive shaft was pre-determined," says Pollard. "You need a fairly large site to set yourself up, and this kind of work couldn't be done from a substation simply due to the amount of assets involved. The Taylor's Lane shaft is novel like this, originally going to be in a substation, we found cables completely obliterating the route, so we had to come out the side and divert water mains involving special arrangements with Thames Water.

"The Brentfield Park [greenfield] site became available, a few other sites had been looked at, but this hit all the right buttons for UKPN, and the Brent local council was a willing party as a result of promised landscaping works."

CONTRACTS

The main civils contract is worth GBP 10.2M of a GBP 15M (USD 23.85M) total project pot. Awarded to J. Murphy & Sons at the back end of 2011 as an NEC Option A lump sum contract. Pollard adds, "It's quite novel in tunnelling, but that's the way the client has gone, and our Newcross contract coming up with them will be the same.

"An Option 'A' Contract transfers considerable volume of risk to the contractor with regards to ground conditions whereas the majority of tunnelling projects undertaken by JMS have been shared risk NEC Option B Target Cost or IChem E or similar."

Murphy is working alone, without a JV partner and no subcontractors for main works, e.g. excavation.

Design is more of a mixed bag with the tunnels designed in-house at Murphy, while Donaldson Associates handled M&E design on behalf of Murphy, providing a functional specification, which is then delivered as the main contractor's own design, based on knowledge of client requirements. Shafts and surrounding structures (as well as the end-use cable brackets) are handled by Parsons Brinckerhoff as the client's designer.

SHAFTS

The two main shafts were sunk by 5t excavators – mini diggers with catalytic converters – and are lined with underpinned FP McCann rings down to the tunnel eye level where the line switches to SCL for the ease of taking on that work. This is mainly to avoid putting in large steel jams and picture frames, which is quite awkward and cumbersome. At the interface between rings and SCL the team placed Tam tubing, something could be injected at a later date if any cracking appears but probably won't be necessary as the tunnel is very dry, with good quality London clay throughout.

The original shaft design by Parsons Brinckerhoff envisaged precast rings all the way to the bottom, but Murphy raised the issue with the steel jam and the time it was going to take, and so requested the spraying programme for the concrete eyes be extended for the remainder of the shaft depth.

The smaller shaft was SCL only, and not circular, but tapering towards the top like a chimney.

For all shaft dimensions, see works outline box.

Outline of works

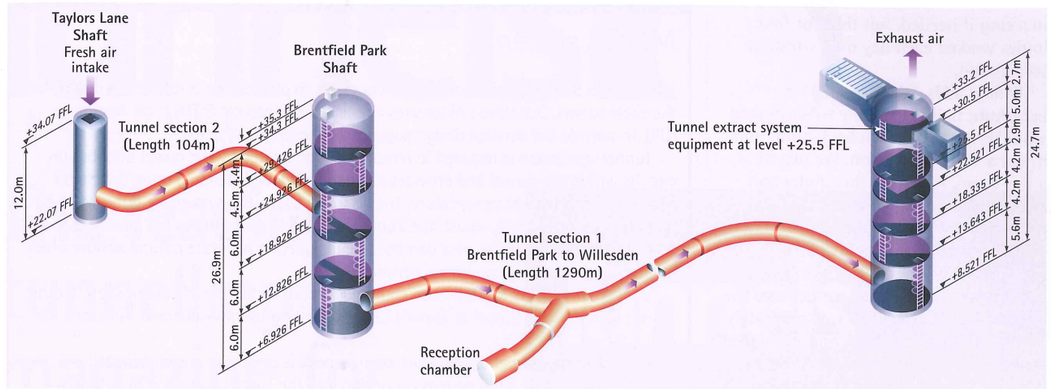
- A 28m-deep drive shaft at Brentfield Park of 7.5m internal diameter, portal eye and base slab in precast segments, with SCL at lower levels around several tunnel portals
- A tunnel of minimum internal diameter 2.59m in Blue London Clay from Brentfield Park to Willesden (1,250m)
- A 29m-deep reception shaft at Willesden of 7.5m internal diameter, with lower levels constructed in SCL with portal eye and base slab
- An SCL shaft at Taylor's Lane with an internal diameter of 4m and 15m deep
- A 2.44m internal diameter, 100m tunnel to connect the Brentfield Park Shaft to the Taylor's Lane Shaft
- A Sprayed Concrete Lining Junction, Reception Chamber and a 22m long connecting tunnel for future recovery of a TBM

Project timeline

- Contract with UKPN awarded to J. Murphy & Sons on 28 September 2011
- Site preparation works 10 October 2011
- Shaft sinking at Brentfield Park commenced in December 2011
- 100m of high level 2.44m ID bolted & grouted tunnel was constructed from February to April 2011
- Brentfield Park shaft constructed to full depth of 30m and temporary works for TBM launch (i.e. backshunt and forward eye) formed in SCL from May to July 2012
- Tunnelling with Lovat TBM commenced at Brentfield Park on single shift basis 11 July 2012 with a best shift completing 23m per single shift with 138m per week a maximum output
- TBM 'Bernice' junctioned at Willesden reception shaft on 6 December 2012
- Junction chamber and spur tunnel future TBM reception chamber commenced 14 January with completion at the end of March
- Main civils works completion was at the end of April, with MEICA installation testing and commissioning carried out throughout the summer
- Reinstatement of Brentfield Park in August
- Project completion and handover to client UKPN, including staff training at the end of August

10.2
The value of the main civils contract in GBP millions, of a 15 million total project pot

Alex Conacher
The *Tunnels* deputy editor has been with the magazine since 2010



TUNNELS

The 1.25km-long main tunnel is built with 2.59m id expanded linings and excavated with a Lovat M116SE Series 11400 machine that was bought and refurbished by Murphy following a Thames Water Ring Main project. Two 17m radius bends were required after launch.

Pollard recalls, "It was quite a challenge – 17m on the Lovat. A lot of pushing on one side is involved."

The 100m-long higher-level tunnel is lined with a Buchan 2.44m ID one-pass bolted grouted lining. This tunnel has two very tight 20m radius curves to be negotiated. The backhoe machine needed to "snake out very, very tight, then swing back in again," says Pollard.

"That's the minimum radius, you definitely wouldn't want to go any further. This is all done to keep under the public highway, which we follow all the way through.

"You have got to stay inside the curve. That is the key thing I say to my engineers: start early, and stay inside. If you don't do this, it's almost impossible without going into the front of it and practically put a plough in and try to dog the front end over. We put beading on to give a bit of overcut, but if you put too much on you sacrifice settlement control.

"We've had good settlement figures, at about 3-4mm once moving. Of course when you first launch it is a bit higher, and while we were negotiating the 20m radius, the settlement was more in the region of 6-7mm. This is because the machine is going slowly and there is time for the ground to relax behind the machine. The quicker you go, the less settlement from expanding London Clay."

Above: Figure 1, Alignment and shaft layout for the project

STUB

A stub tunnel has been excavated to future-proof the project. It's a reception chamber to receive a TBM should there be any later need to connect into the construction. It is not possible to bring a TBM into the tunnel containing live circuits, so a branch-out is needed.

MACHINE LAUNCH

The machine was not launched from a frame. The team came up with a novel solution. When the high-level tunnel machine was launched, a thrust ring was put in and an eye sprayed to the length of the machine to put it in. "The other one, we've never done it before," says Pollard. "But we sprayed an eye big enough to put the machine in, which saved a thrust frame or pit irons. We had the conveyor belt in short mode and it just fit inside the 7.5m launch shaft.

"We built the shove ring behind the machine, Donaldson Associates did the check on temporary works. A webbed frame with gussets, fixed with hilted fixings and grouted saved many days at the pit bottom before launch. You need good ground conditions to do a sprayed concrete eye. We did it with Ellie [the backhoe machine] at the top, and we thought as long as the numbers worked we would do it at the bottom. You can't shove with great pressure, just having to ease it in until you are say half a dozen rings in, and then you grout up that bit behind the shove ring."

The idea was from a combination of the Murphy site team, and the team from the company's Kentish Town yard. "Sean Martin who was in charge of TBM refurb deserves special credit," adds Pollard. "It simplified launching the machines and shortened the programme by saving breaking the machine up and putting it down in pieces.

"The method allowed for a quick and simple, controlled start to the tunnelling operations. Lowered onto shaft on a Thursday in mid-July 2012, connected and shoved into the forward eye on Friday, tested and commissioned mechanically and electrically on Saturday and Monday, with tunnelling commencing on Tuesday."

> "You have to stay inside the curve, that's the key thing. Start early, and stay inside"

MUCKING OUT

Mucking out was done by a crane raising Mullhauser skips, a secondary rope being attached to the skip to tip it. A train could be turned around in 10-12 minutes with the setup on site. Spoil was removed by road and there was a muck bin capable of storing a full day's

mucking if needed, but three or four lorries worked each day on a constant turnaround.

Pollard adds, "We had an 11m backshunt built. Originally we envisaged a bunker pit and a 30m backshunt, and it was a time comparison. We played a few tunes, looked at the production rate of raising these new skips...and realised we could split the train and by shuttling around we could still keep the TBM fuilly stocked by having two trains working. A subtle change from the original idea that worked well and safely.

"We needed new stock and we looked into this...originally there would be six skips per ring and that was the reason for the full train with 30m backshunt. We needed new skips and we ended up buying these. We were doing 3 rings per shift so approximately 12 skips per hour. You could get train emptied and segments put on by the time the other train came out. We were busy at first but easier as the distance from to the machine increased."

FIBRE FREE

Parts of the tunnel have been constructed without fibres – polypropylene or steel – at all.

Simon Stroud of Parsons Brinckerhoff explains, "The junction chambers and connection adit were designed by the Parsons Brinckerhoff team using a thrust line approach. As such the design only required compression capacities to be satisfied. The benefits steel fibres bring relating to tensile capacity were therefore not required and as a result steel fibres were not included in either primary or secondary sprayed concrete layers allowing greater flexibility for J. Murphy & Sons in excavation and application sequences."

Pollard adds, "Now we know for a fact that some consultants won't put sprayed concrete in without fibres. But Parsons Brinckerhoff are quite happy if they look at K0 factors and everything else that if the whole thing is acting in compression then it's not needed. It's not something we've ever done before, and talking to other engineers, designers often go 'belts and braces' [i.e., extra careful] with SCL. You read opinions in the magazines where sometimes a 200mm thick lining is fine, but when you go SCL 400mm is needed."

LOOKING BACK

In terms of geology, the area was fairly well known from the start. Site investigation had been done initially so Murphy was "quietly confident" according to Pollard. "Contractors tunnelled here many years ago and I heard a story they claimed the clay was too hard. Normally you would hear that it's too soft, but not here. In the end it was exactly as we expected: good blue London Clay.

"The biggest challenge we expected from the job was to satisfy UKPN of what we could deliver. Not only them, but the subcontractors too. As part of a Safety and Culture Development programme aiming for zero harm, the foreman chairs 10-minute meetings at the start of each day. We discuss what happened yesterday and what's to come in that day. UKPN is actually adopting something similar in other parts of its business. Pollard adds, "I had some concerns over potential crime in the area, and we have a minibus to take workers to and from the station. We also brought in special hoardings. They are manufactured by Kwik-klik and are plastic interlocking barriers that are graffiti resistant. A solvent cleaner just washes it off. While pine hoardings would just be waste material by the end of work, this can be reused, making it more environmentally friendly.

"Everything's gone pretty well on the project. The staff has gone right through"

MEICA systems

J. Murphy & Sons engaged Donaldson Associates to provide the construction design for the cable tunnel. Donaldson Associates appointed Mechanical & Electrical Associates (UK), to provide the detailed design support for the MEICA systems.

Tunnel ventilation is required to remove heat generated by the power distribution circuits within the tunnel and provides a variable airflow depending upon the circuit heat-gain and ambient temperature. The design is a two-fan system for duty-stand-by operation as well as duty-assist operation: fan variable speed drives are provided. As an energy saving measure, by-pass dampers are included to facilitate natural airflow when ambient and operating conditions permit.

Ventilation plant is located in an equipment room within the Willesden shaft: fresh air is drawn into the tunnel at Taylor's Lane exhausting to atmosphere at Willesden at ground level.

Control of the tunnel temperature environment is by means of a Distributed Temperature Sensing (DTS) system connected into the Tunnel Control & Monitoring System (TCMS). The DTS monitors the tunnel crown temperature as well as power distribution circuit temperatures and is also used for fire detection and alarming through the tunnel sections; separate fire detection systems are provided for shafts and the equipment room.

The tunnel layout is represented graphically at a HMI on the ICA panel and includes key operational information as well as events and alarms. Setpoints as well as trends and reports pages are provided.

Alarms and events from the tunnel ventilation plant and systems are sent to UK Power Networks via the tunnel control and monitoring system.

The solutions adopted for cooling and monitoring the Willesden to Taylor's Lane Deep Cable Tunnel are fairly standard for UK Power Networks. Ventilation plant located within a shaft in many ways is similar to locating ventilation plant within a substation where there are space limitations and tortuous exhaust routes.

The advantage, placing the ventilation plant inside a shaft, eliminates the need for a head-house arrangement, thus saving building costs and additional land take. Visually, there is nothing seen above ground level.

Co-ordination of the various system specialists has played a big part in the installation, in so much that working in a confined space needed carefully organizing to avoid conflict of working space by the various trades, which has been down to J. Murphy & Sons programming. That in particular has worked well.

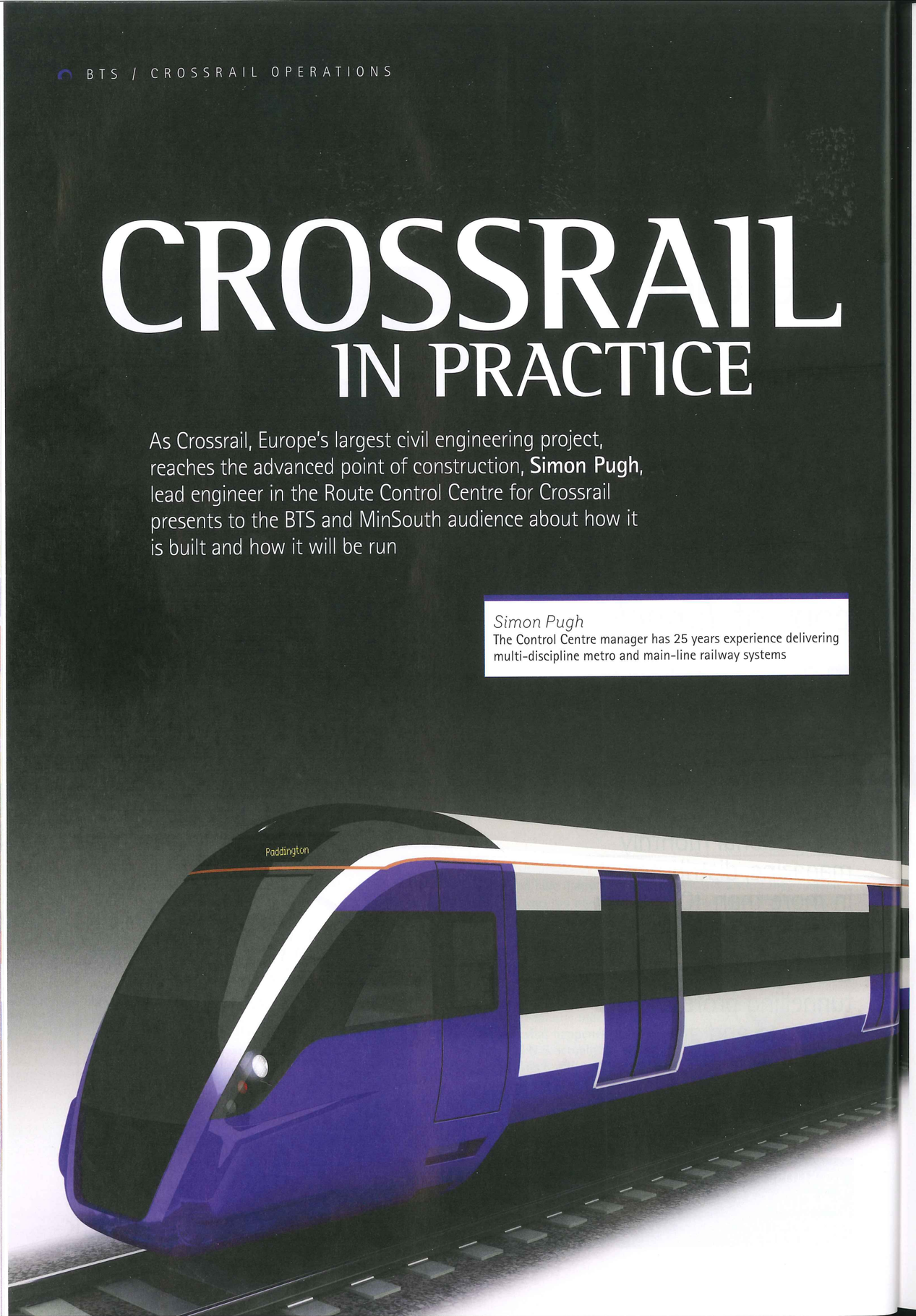
Also, the design of the TCMS will again on this tunnel prove to be of significant benefit to UK Power Networks, being able to monitor the tunnel remotely, the system being a development of systems designed for previous cable tunnels.

Phil Green, director
Mechanical & Electrical Associates

CROSSRAIL IN PRACTICE

As Crossrail, Europe's largest civil engineering project, reaches the advanced point of construction, **Simon Pugh**, lead engineer in the Route Control Centre for Crossrail presents to the BTS and MinSouth audience about how it is built and how it will be run

Simon Pugh
The Control Centre manager has 25 years experience delivering multi-discipline metro and main-line railway systems



THE CROSSRAIL project is truly large scale. It provides vital capacity for east-west links and accessibility into central London and core business districts, links with the London Underground and improves connectivity of Great Western, Great Eastern and South East sections of Network Rail. The link is 118km long from west to east and will have a capacity of more than 200 million passenger journeys a year. The central section will run 24 trains an hour (average every 2.5 minutes) in each direction and for the most part will be underground. More project statistics include the construction of 42km of tunnels, 37 new stations including eight sub-surface, more than 60 lengthened platforms, the removal of eight million cubic metres of spoil and 140 main works contracts. The total infrastructure budget is GBP 14.8bn (USD 23bn).

To accommodate the planned passenger capacity in the central section, the trains will be larger than those on today's underground system, with each extending more than 200m and requiring tunnels with a diameter of 6m. In comparison, the Victoria line tube tunnels are 3.81m in diameter and the Channel Tunnel some 7.6m. Eight TBMs are constructing tunnels up to depths of 40m below surface.

The majority of the geology of the central section is London Clay, a stiff blue-brown clay that underlies most of central London. Below this is the Lambeth Group - up to 20m of sands and clays, the Thanet formation - up to 16m of fine sand and the underlying chalk. In the west of the central section, London Clay is dominant from the portal at Royal Oak through Bond Street, Tottenham Court Road and Southampton Row (Fisher Street), beyond which an anticline brings the Lambeth Group nearer the surface and where the tunnels will follow the approximate boundary between the London Clay area and then this group.

Further east, the Millwall anticline brings the Thanet Sands of Palaeocene age (54.8-57 million years old) near to the surface, while at the Victoria Dock portal the tunnels are back into London Clay. On the south side of the Thames, the North Woolwich portal takes the tunnels into the Chalk to Plumstead and into the Thanet Sands at Woolwich Station.

When tunneling in an urban environment, the prime consideration is to ensure zero ground settlement, which can affect the structure of the buildings above.

TBM development has led to shielded machines that can extract and transport spoil at the same rate as tunnel advancement - called earth pressure balance machines. Six of these will be used in the central section, while two machines used within the chalk will be slurry shield TBMs to cope with soft ground and high water flows in the section between Plumstead and North Woolwich.

The method of lining the tunnels is partly determined by the geology resulting in a mix of sprayed concrete lining (SCL) and bolted pre-cast segments, the latter being cast at tunnel portals with the first plant built at Old Oak Common, near Acton in west London.

The tunnels are not the only underground constructions for the project. Bigger stations are required to accommodate the larger trains that will run on Crossrail and to meet the projected capacity a fleet of 65 new trains is required, each with a capacity of 1,500 passengers. Power for the trains will be via 25kV overhead cables and will support faster accelerating and braking.

A braking energy recovery system will be built in that will reduce heat generation in the tunnels. With increased passenger loads over current underground trains, the design engineering has to maximise the passenger flow in and out of the carriages.

> "When tunnelling in an urban environment, the prime consideration is to ensure zero ground settlement"

Left: Crossrail rolling stock has yet to be designed

CONGESTED UNDERGROUND

The construction of larger stations has been an equal challenge. In the central section, the historical legacy of London's sewer system, water and electricity supply, large building foundations and the Tube lines have created difficult civil engineering environments for Crossrail. This is compounded by the established interconnections with existing underground and surface stations that are often in crowded parts of the city. An example of the challenges can be seen at Tottenham Court Road where the existing station, built as two separate tube platforms more than 100 years ago now hosts 150,000 passengers' journeys daily. Crossrail will add to this a new station with 260m underground platforms at 25m depth; a new eastern ticket hall on Dean Street, escalators to the existing Northern line platforms and a new ventilation shaft.

The 'box' containing the new Crossrail station and interchange facilities all have to be built on a much-expanded footprint confined by Centre Point and Charing Cross Road. On site are a huge amount of facilities buried just below the surface, making the job extraordinarily difficult and requiring diversions at street level in and around Charing Cross Road and Oxford Street. The 'box' is constructed of reinforced concrete base and perimeter walls.

RCC

The role of Route Control Centre (RCC) is to control the trains and infrastructure of the central section and also to ensure seamless integration of Crossrail services with the Great Western, Great Eastern and South East parts of Network Rail and the London Underground network. This integration of new and existing systems is an enormous challenge. All facets of service operation are governed through a suite of Crossrail-specific operational concepts, which direct operations, safety and maintainability. Moreover, these ultimately determine how the performance, capacity, the command and control and the operational interface with other infrastructure managers are provided.

One of the major challenges within

23
The total infrastructure budget for delivering the Crossrail project in USD billions

42
The number of kilometres of tunnels that are currently under construction for Crossrail

the project is combining existing network services, with the high-frequency mass transit systems that Crossrail will provide. This includes the traffic management challenges of delivering a railway that will have to interface to existing timetabled, governed routes that at the same time ensure, where possible, even headways through the central operating section.

In late 2012, Crossrail let a contract to a consortium comprising Siemens and Invensys Rail to install a communications-based train control (CBTC) signalling system for the central operating section, which controls the section linking Portobello Road in the west, Pudding Mill Lane in the east and Abbey Wood in the southeast. This system will allow the control of trains that will take into account the possible delays and gaps between trains by automatically adjusting their speed through a series of interlocking control systems, fixed position and on-board train position reporting and movement authorities for each train, determined from central controllers that have interlocking interfaces.

The driver has in-cab signalling equipment and displays and features such as automatic train protection, automatic train operation and automatic train regulation will be provided, including trackside reporting of train position. As the number of trains per hour in the central section will be far greater than those on the Great Western and Great Eastern Network Rail sections, it is planned that there will be an automatic train reversal system of up to 14 trains per hour beyond Paddington at Westbourne Park.

Three control centres (Great Western, Central and Great Eastern) will manage Crossrail services and integrate with London Underground and Network Rail. Crossrail has already made a model for control centres that will allow functions of supervisory management, signalling and regulation, engineering management (of fixed equipment, such as power and ventilation), train management and customer services control. While the new RCC control centres provide new, integrated control and operational management.

It's important that centres do not risk unwarranted distraction between safety and support roles and that the need for a back-up control is also addressed. Integrating Crossrail is a complex problem, but when the central operating section is operational in 2018, it will provide 10 per cent additional capacity for east-west travel in central London.

"Disability access is fully designed into all the new stations. [Crossrail is] fully useable for passengers with restricted mobility on all the new stations"

QUESTIONS AND ANSWERS

Question 1

As a member of Min South, I am not as familiar with all the aspects as our tunnellers here, but the one thing I was just wondering is the disability access and how that is built in, particularly with 24 trains coming through an hour and some very busy places and people coming in from Heathrow or shopping in Oxford Street, so my question is how is disability access built into the systems?

Gavin Bowyer, Min South

Answer

Disability access is fully designed into all the new stations. It's fully useable for passengers with restricted mobility on all the new stations. There is a huge amount of work being done. One thing I didn't include because of timing, I took a slide out about what is happening on the network.

Building new stations is relatively easy, to make sure we have lifts, but there is a lot of on-network work being done. We have 37 stations across the route and there is a huge amount of on-network work being done by Network Rail.

There is GBP 2bn (USD 3.1bn) worth there. There are a lot of works ongoing to do the station upgrades to achieve that, but for all the new stations, the new Central Section Stations, Sub Service Stations, all of that is engineered in, but it's not just about lifts and escalators, it's about level access into the trains, it's about the design of the trains, so from the full end to end of accessing to egressing the individual's journey on the Crossrail route.

Question 2

Just a follow-up to that question on the disability issue. If you could just imagine a passenger, say getting on at Maidenhead, wanting to go to some station that's not an actual Crossrail station, but at some station on, say, the Northern Line where it may not be fully accessible at the moment, will there be a system in there, that a passenger getting on at one of these other stations can readily appreciate his whole route. So will there be a proper information system that will be able to alert that passenger before they board the train?

Mike McConnell, retired from Balfour Beatty

Answer

The short answer to that will be, yes. The Crossrail train operator, which will be appointed relatively shortly, will ultimately be responsible for the whole information provision to deliver that and they will have to own both that level of information, but also to handle specific individual requests and even to look after them.

I'm thinking about blind access and having people to meet, but in order to do journey planning - we want it to be quite a smart railway and we want to think how much technology do we want, but putting that aside because of course we all expect various apps and things to be there, but to be able to provide that information or get that information, be it from a help point on arrival at the station, perhaps having some sort of smart kiosks to identify where you want to go and whether or not, if you have some mobility issues, how that will be delivered.

Question 3

A question about the operator. Crossrail is going to be appointing the operator - is that correct and when and what's the process, particularly in light of a little bit of difficulty that perhaps DFT, who have done this sort of thing before, have had recently with appointing operators.

Mike Napier, Costain

Answer

I will answer what I know. The operator will be multiple. The infrastructure manager for the central section will be Rail for London so they will maintain the rail, the signalling and such like and they will also operate signal and provide some of those core safety roles I have illustrated in the Route Control Centre, so there will be an operator there. The operator, the concession that is going to be let for the Crossrail train operating company, that is being done over the next two years relatively quickly, because the first time you start to see Crossrail will be when that TOC starts to take over on the Great Eastern.

I am not the expert here, I will tell you what my best understanding is, and that might even be before the new trains arrival or in parallel with that and services with eight car units, rather than probably 10 that we will have will then operate and just replace the existing service today into Liverpool Street. So the second part of your question, which I almost certainly can't answer, all to do with the sort of politics and the conflicts, and of course it's been hot in the press with what's been happening out on the Great Western. I'm your engineer, not an end engineer, thank God.

Question 4

I have a simple question; will passengers be able to use their mobile phone to access voice services and the Internet?

Nick O'Reilly, Min South

Answer

It would be sinful if they couldn't. However, there is no contract at the moment to deliver that, but I can't imagine it opening without that. There are discussions ongoing - I mean of course it's a matter of who can pay for it and that sort of thing. There are some conflict issues with what's happening.

I mean you've got that today on the Heathrow lines, but the various upgrades on one of the GSMR are... you know there's issues, engineering issues, technical issues being looked at because everyone will want 4G but we are not going to be getting into Crossrail for another five to six years.

It's going to open in stages - I was told not to put any stage opening slides up tonight, but we are not going to be up and running on the central section until about the end of 2018 or early 2019. It's still a number of years off and 5G will probably be talked about. Just talking personally, it would be highly surprising if it was not provided, because we are dealing with business travellers going into Canary Wharf, into Heathrow and the like.

We've got these, what my son calls "first world problems," with people wandering around using their phones perpetually and I do it and I don't like other people in front of me doing it, but we all do it and we all expect it. It's the way of the world.

"It would be a sin if [passengers couldn't use mobile phones on Crossrail]. However, there is no contract at the moment to deliver that, but I can't imagine it opening without that"

65

The projected size of the new fleet of rolling stock to meet requirements

1500

The passenger capacity of each of the new Crossrail trains to meet user demand

Question 5

At the Transport Asset Management Conference held here in London last November, a presenter from the European Rail Agency gave a presentation on the challenges for European rail integration and, perhaps rather unfairly, held up Crossrail as a bit of a lost opportunity. His way of presenting it was that it was going to be another railway with its own rolling stock and its own requirements and its own signalling flavour of ERTMS and taking European standards as inspiration, but not necessarily fully applying them.

I just wondered if you had anything to say about that.

Adam Noakes, Mott MacDonald

Answer

We have had to take concessions and dispensations from the European Community to do what we're doing. We're doing the right thing to manage our risk and our requirements when looking overall at what Crossrail has to do in terms on any operability, so it was getting concession to make sure we didn't incur costs or risks that the project wasn't prepared to take on board. Ultimately we're building a new railway and we have all those rules out there so why aren't you complying with them? A lot of people worked quite hard and sort of delicately on that. Ultimately we had a sort of robust case to put forward.

Question 6

You spoke a bit about responsible procurement and you mentioned apprenticeships, so my question is about local supply chains and I don't know whether you can comment about what you experience in that area. Whether you are able to find any success stories around this area within the works packages that you spoke about or just generally your experience of having to deal with requirements for local supply chain from TFL especially.

Jillian Lilico, Demeter Development

Answer

That is a question that I can't answer, but I can put you in contact with people that do. I am not aware about the local supply chain having to engage there. We certainly have to engage and promote local workforce. My knowledge is from my own sort of systems area. We take questions, but I can't take on board not to answer them personally, but if you wanted to know an answer to that question, I could put you in touch with people that can help. I said at the beginning of the presentation that I am who I am and Crossrail is massive in every which way, whether it's in engineering or in a commercial activity.

Question 7
You mentioned various contracts and, in particular, the signalling contract and I heard the name Siemens, but I couldn't help hearing that and wondering how many companies there are worldwide who can actually fulfil a contract like that.
John Murphy, URS

Answer
Our contracts are big. The biggest systems contract we have is something called the C610, which is sort of tunnel main works to come and do power and M&E fit out and such like and what we are seeing is that you get big companies and even then going into partnerships. So, on the signalling I think we had nine that we then took through pre-qualification and got five to bid. I won't say the names, but one dropped out because they just couldn't fulfill two large contacts they had and another one withdrew so we were left with three on that. With the C660, which is a similar size of contract, we are talking many tens of millions of an initial contact value. That's for the controls and communications that were going between eight or nine stations, communication systems, radio and fibre networks. Crossrail data networks is a C660 contract, we are down to three.

We had five on that one, but two dropped out and so we've got three left. So there are not many and we want a proven product, sort of CBTC signalling product and there are four or five big companies. They've all got products and it's not just the technology, because the technology is out there, it's having the commercial and the ability to support the contract values and the ultimate guarantees, commercial guarantees, legal guarantees, indemnities and all those sorts of things that Crossrail requires. So it's more than just the technical capacity. But you generally tend to have big companies who will do that. We have a very robust procurement to make sure we have the right thing and it's generally biased in terms of, weighted in terms of the right technical and low risk sort of project solution, rather than just the initial headline cost.

Question 8
I had a question on the heat rejection of the train. On the rolling stock you were saying that they have regenerative braking. I would like to know what kind of figures are you expecting from the rolling stock manufacturer. And then the second question was the ripple effect of that on the C610, the M&E or the contract, which is responsible for keeping the stations and the tunnels cool at whatever temperature, 27, 28 or under 30. The interface between the two - what if the first contractor of the rolling stock cannot provide that kind of heat of the regenerative braking so that the heat is reduced?

How have you managed this interfacing between the different contractors, which is very difficult?
Mohammed Tabara, Arup

"Travellators are expensive. There are no travellators in Crossrail, nor are there any excessive transits [unlike on] London Underground"

Answer
I don't have any figures for what has been calculated and, actually, we don't yet have a contractor for the rolling stock nor a contractor for the ventilation system. For heat that is generated by the train there are various modes of operation of our tunnel ventilation system. It's primary role is to do smoke management, but to then manage an excess build-up of heat that could risk the operability of the air conditioning and the comfort of the people on board, we have extract systems in the stations to manage that, as well as shafts at each end of each station. I think what you are illustrating are a huge amount of systems integration in this case it's not just computer systems handshaking and exchanging timetable information, but it's doing a sort of physical dynamics. All we have is a very robust interface that covers this kind of interface arrangement and all these issues have already been assessed to a degree by design assumptions and performance constraints and suchlike during the reference designs with our framework design consultants and have gone into the works information and had design engineers looking at that and now we've ultimately got to have people delivering against that and making sure that their deliverables comply with those requirements. But I don't have the particular figures to hand.

Question 9
My wife complains when she gets into St Pancras on the High Speed One that she has to walk a very long way to connect to the other tubes and so on. Would you be putting travellators in and luggage handling, because one of the things that deters people from using the trains if you have luggage, is that it is much easier to take the car because you've got luggage handling, but are you doing something about that, because it is a deterrent. And secondly, you're not using any lithium batteries, are you?
Mike Brooks, Min South

Answer
Travellators are expensive. I know that they were looked at as a link between Stratford International and Stratford existing London Underground exchange and that wasn't put in and there is a DLR extension to cope with that. There are no travellators in at Crossrail nor are there any excessive transits. There are one or two. I was on one the other day at Green Park or somewhere. There are one or two on the London Underground where you think you need a travellator. In fact I was on one at Waterloo the other evening, but we don't have any links of that length between Crossrail and London Underground. There are lifts if you are mobility impaired, and if your mobility is impaired because you are lugging luggage then you will use lifts. All that, I trust, by our station designers has been fully taken into account and not like my experience yesterday at Westminster in trying to transit up to the District and Circle line level from the Jubilee, you have to go up to station level and then down so you can do it in lifts but not just in one journey. You have got to change your lifts.

Lithium batteries. I don't know but it wouldn't surprise me if rolling stock or such like bidders, their designers of products could consider that.

Obviously I know that in 787s and I like my aeroplanes and I'm getting on one next week. Obviously they are all grounded anyway, but I want to see them up in the air as soon as possible. The latest solutions I see there is they are going to try and get the FAA to let them fly, by containing possible risk of fire and venting the gases to the outside rather than the redesign that would take, perhaps, a year or two. I don't know about that but I'm sure the contractors have thought about that. I have to think about rolling stock. We have a lot of back-up batteries for things like signalling systems in signalling centres, but there are a lot of good old lead acid kicking around there to do UPS and suchlike. But I do wonder about the trains. I don't know. You've posed a question I don't know the answer to but I am sure the big names who are bidding on our rolling stock if they are thinking about that will perhaps be backtracking quite quickly.

Question 10
I have always thought that one of the biggest challenges to Crossrail is integrating what is essentially a Metro in the central section with a timetabled railway on either side, particularly as these trains are very large for Metros and are going to handle a huge number of passengers. Also the dwell times and the congestion is going to move from station to station during the day, which is not really easy to predict right now as the system matures. The question is in two parts. How robust is this system to cope with that and has it ever been attempted anywhere else in the world? Are there other examples, similar examples, or are we boldly going where no man has gone before?
Dave Hindle, OTB

Answer
In concept we are not going where people have never gone before, but in terms of the demand that we are looking to do, we are pushing new boundaries there and I think, without doubt, that I tried to do some sort of validation comparison of control and who else has solved this. It is a big challenge. It's easy for us as I said in the presentation, to move that responsibility on to the suppliers - to say look you can deliver a new signalling system, you can put all the fancy technology and software on there, we will work with you in terms of what's feasible for a signaller to do, because that's all new and existing and we can easily accept and change that. Where we've got to integrate with both existing Network Rail practices and organisational structures about how many people and how they communicate and operate that and what ability Crossrail have got in the Central Control Centre with the person who is the train running controller top manager, how can he influence that regulation of others and he's heavily constrained in doing that and you're only as good as the information you've got, so we're going to put in this big sort of overview display, but that is a passive thing, but in terms of the alarms, that are going to start to tell you and warn you about information, about what levels of things you can deal with automatically so that the Signaller can concentrate on bigger perturbations of the system, can automatically make what's called sort of adjustments to the automatic timetabling because all the routes have to set automatically - you don't have a signaller who is going to automatically call routes and the system is going to manage the dwell times or handle the level of swapping trains around maybe bringing one out of Westbourne Park ahead of the train that's running late off the main line and such like.

There's a huge amount of work to be done on that side and keeping me busy, so I have every confidence.

Dave Hindle: It's very ambitious isn't it?

It is very ambitious, but it's not overly ambitious.

Dave Hindle: No, I'm just wondering if the system is designed to be robust to cope with these inevitable huge variations we see.

Well the Central Section, there's two elements of the system. One is that physically, can we move the actual train, do we have the power and do we have the headway that signalling, but then it's about the decision making and the operator all you have to do is do the wrong thing and then you've got a hold up of trains and the whole thing can just fall apart very carefully.

I think the ultimate timetable that is run in terms of where trains go from and to will be dictated to the Central Section so that's everything going down to Abbey Wood is within our gift to control and regulate and I think the central section will be constrained in exactly how it delivers its service in order to safeguard the interface onto the network.

The other thing is the systems that we have on the network, we've got to interface with those and then we said we need all this information for all of these services. You tell us what the predicted delay is when a train is pulling out of a platform in Maidenhead it will be easy to say, but again that would cost money for Network Rail to deliver so, Crossrail has been going in its current actual happening phase for seven or eight years from an engineering standpoint, taking it through Parliament and we're halfway through the actual engineering and we're doing the real designs and tackling things that so far have been scripted. This engineer's going to be employed and challenged. Invite me back in five years time

Rapporteur: Alan Bozeat

24
The number of trains per hour the central section of Crossrail will run, operating as a metro system

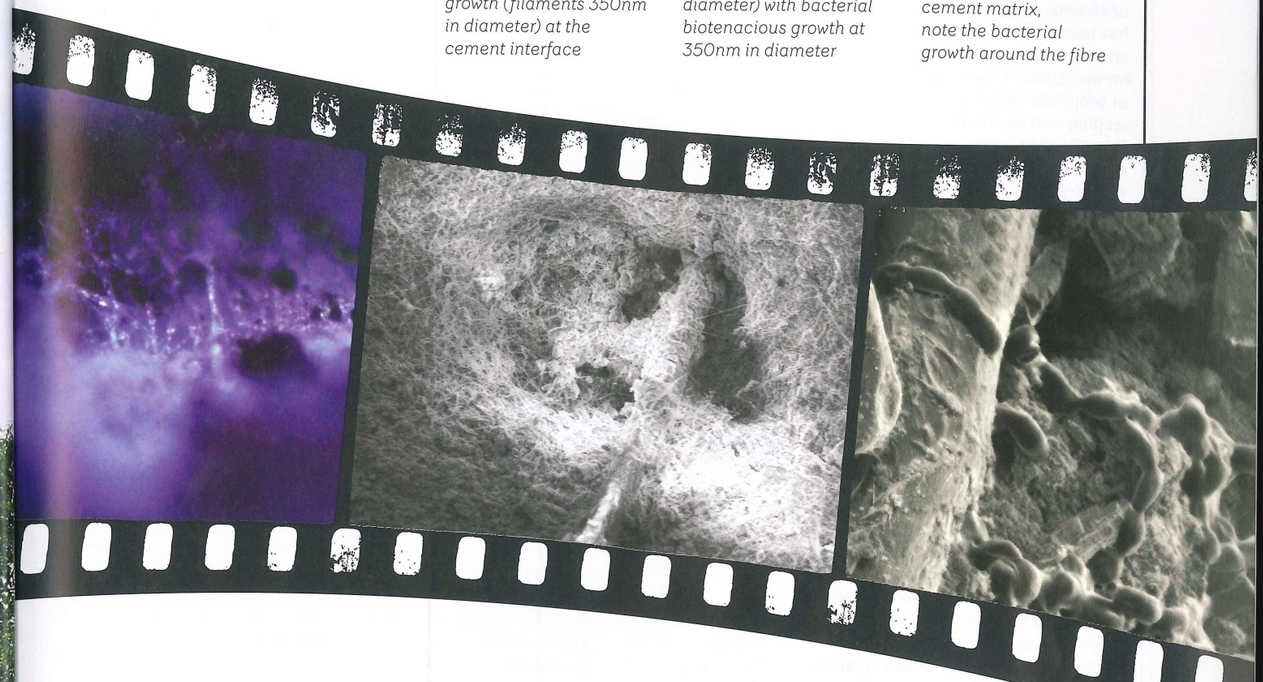
200
The number of passengers in millions that Crossrail is capable of handling yearly

"In concept we are not going where people have never gone before, but in terms of the demand that we are looking to do, we are pushing new boundaries there"

Below, left: Figure 1, Bacterial biotenacious growth (filaments 350nm in diameter) at the cement interface

Below, middle: Figure 2, micro-fibre (22µm in diameter) with bacterial biotenacious growth at 350nm in diameter

Below, right: Figure 3, Micro fibre within the cement matrix, note the bacterial growth around the fibre



GERM WARFARE

Peter Hughes of the University of Central Lancashire, UK, looks at the effects of spreading biological material on concrete linings in tunnels

Peter Hughes
Peter is a final year PhD student at the University of Central Lancashire, UK, investigating marine biofouling and its implications for the durability of marine concrete

CONCRETE DURABILITY in tunnels is essential, as failures in the past have led to the loss of life. There is a tendency in sprayed concrete, whether used in tunnel works, or in open-air applications, for biological cells and debris to accumulate on the outer and inner surfaces of concrete. This further attracts moisture, which may facilitate chemical reactions and promote the growth of bacteria (1).

Tunnel excavation work for a new Ring Rail Line under the eastern runway of Helsinki-Vantaa Airport in Finland has been delayed, due to interesting and unexpected phenomena. From the ground above, breakdown products of propylene glycol were found to be seeping into the tunnel, originating from de-icing agents used on aircraft at Helsinki-Vantaa. When interacting with oxygen, these products facilitate the formation of a certain microbe population in the water seeping into the tunnel and on the tunnel walls. As a consequence, the construction budget keeps growing and according to the Ministry of Finance, the cost-estimate for the additional work has reached EUR 50M (USD 66.8M) (2).

Microorganisms such as bacteria and algae have been widely reported to be involved in the deterioration of concrete (3) (4). However, relatively few direct relationships have been established between the activities of microorganisms and synthetic fibres within concrete, in harsh environments such as tunnels. It has been reported that steel fibres within sprayed concrete were severely attacked by bacteria (1), and synthetic fibres have also been observed in a marine environment to be susceptible to microbial colonisation (5) (6).

It is claimed by other researchers that some species of bacteria may enhance the durability of concrete, however, it is the view of the author that filamentous growth is detrimental to the durability of synthetic fibre reinforced concrete in harsh environments. In related studies by the author, the degradation of synthetic fibres have been observed in a marine environment over the eight year lifetime of a sea defence scheme in the UK (5).

It is usually accepted that a watertight concrete is durable. Once water tightness is lost however, the interior of the concrete may become saturated; allowing microorganism's carried in water to play a greater active role in deterioration. As the microorganisms are transported into the matrix of the material they will contribute successive cycles of expansion, further cracking, fibre de-bonding and liberation leading to increased permeability, see figure 1.

The occurrence of bacteria in concrete tunnels was reported in 1934 (7); highlighting an interesting and serious problem, by the appearance of Crenothrix, a type of bacterium found growing in the ground water in the Hetch Hetchy water system (USA). This seepage water, having a high mineral content and containing the Crenothrix organism, flowed through the tunnel and carried the microorganism into several lines of conveying water. After intensive study, controlling the organism with a chlorine-ammonia treatment was used. Algae have also been commonly observed within subsea tunnels clogging of drains (8).

> "It is claimed by other researchers that some species of bacteria may enhance durability"

Right: Figure 5, Algal filamentous growth (30µm dia) penetrating through the synthetic fibre (arrowed)

Below: Figure 4, Algal filamentous growth wrapping around synthetic fibre within the cement matrix of marine concrete

■ *The author thanks his supervisors for their endless patience. D. Fairhurst, Professor I. Sherrington, Dr. N. Renevier, Professor L.H.G. Morton, Professor P. C. Robery and Dr. L. Cunningham.*

DISCUSSION

The biotenacious growth on and around the micro-fibres in (Figures 2 and 3) can be likened to the natural process of retting where micro-organism's have been used for many years, in the extraction of fibres from plant materials. Retting employs the action of bacteria to dissolve and degrade the surrounding tissue of bast-fibre, thus separating the fibres. This is essentially an assimilative process, during which organic residues are washed away, leaving the fibres intact. Degradation of fibre reinforced concrete however, is essentially a dissimilative process, but with a similar result.

Filamentous bacterial growth (Figure 3) which can occur at very low nutrient levels, not only wraps around the fibres weakening the fibre/concrete matrix bond, but condition the surface of the fibre, making it more amenable to colonisation by other micro-organisms such as algae (Figure 4). The mechanisms observed and presented in Figures 1 and 2 occur when the material bond is weakened as a direct result of the physical activity of an organism, such as its movement or growth (9).

In cement composites with fibre inclusions the matrix in the vicinity of the inclusion can be quite different in its microstructure to that of the bulk cement matrix. This modified matrix can be as great as 50µm to 100µm (10). The higher porosity at this interface, favours the appearance and development of bioerosive forces in the form of microbial filamentous growth. Experimental evidence from other researchers indicates that porous concrete creates a favourable environment for microbial colonisation, because water-borne organisms including algae adhere to both its inner and outer surfaces (11). The observations reported in this study, particularly the attachment of filamentous organisms, the cohesion between particles, the penetration and growth (seen in figure 5) are comparable to those observed in previous work on boring activity within the concrete of historic buildings (12). This type of deterioration has also been reported in subsea tunnels in Norway (1), where steel fibre reinforced concrete used for rock support was attacked by saline ground waters along the concrete/rock interfaces as well as the outer rough and more reactive concrete surfaces. The process had frequently led to the total disintegration of the cement paste matrix and steel fibre after less than five years exposure and was reported as closely related to the growth of biofilms.

CONCLUSION

Early bacterial biofilm formation within the matrix is the start of the marine fouling process, leading to further colonisation of algae and other microorganisms. This continual growth at the fibre/cement interface weakens the bond between fibre and cement. Filamentous microbial growth around fibrillated polymer and the penetration of microbial filaments through the material is detrimental to the overall durability of the concrete itself. Potential influences of marine organisms on the durability of synthetic fibres in concrete used in harsh environments clearly warrant further detailed investigation

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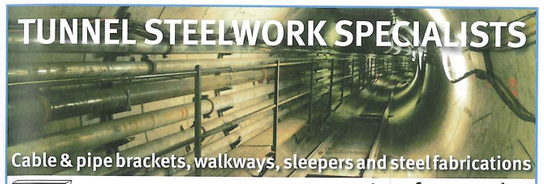

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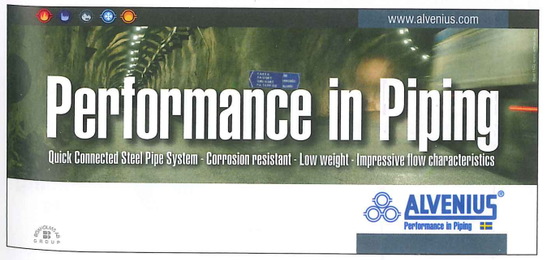

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What's on

2013

SITCE 2013
7-10 October 2013
Singapore
The inaugural SITCE is a platform for urban land transport professionals worldwide to meet and discuss ways to shift the transport focus to people. Planned as a biennial event, SITCE is one of the first initiatives by the UITP Centre for Transport Excellence in Asia-Pacific.
www.sitce.org

62nd Geomechanics Colloquy
9-11 October 2013
Salzburg, Austria
The annual Colloquium of the OeGG. This year's topics include: power water conduits, special measures in soft ground, and international large projects.
www.oegg.at

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

BTS Conference and Exhibition
23-24 October 2013
London, United Kingdom
The British Tunnelling Society's conference returns as the largest event on the UK tunnelling calendar, boasting an exciting technical programme and bustling exhibit hall.
www.bts2013.com

Southern Railway Link Conference Koralm and Semmering tunnels
21 November 2013
Leoben, Austria
The Southern Railway SESSION is a forum to present experiences and discuss case studies to the above tunnels major projects and other projects along the Southern Railway.
www.suedbahntagung.at/index.php

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

2014

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

Eurasia Rail
6-8 March 2014
Istanbul, Turkey
The Fourth International Rolling Stock, Infrastructure and Logistics Exposition features a tunnel construction section in 2014. By 2023, Turkey's Ministry of Transport is planning to build more than 1,100km of rail track. International pavilions are on show from Poland, France, Germany, Russian Federation, Czech Republic, the UK and China.
www.eurasiarail.eu

ISTSS
12-14 March 2014
Marseille, France
The Sixth International Symposium on Tunnel Safety and Security in Marseille, France will discuss current best practice and emerging demands and trends as well as research.
www.istss.se

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

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

North American Tunneling Conference
22-25 June 2014
Los Angeles, California
The US's Underground Construction Association (UCA)'s biennel tunnelling conferece takes place in Los Angeles, California in 2014. The deadline for draft manuscripts in 1 November.
www.smenet.org

2015

World Tunnel Congress
22-28 May 2015
Dubrovnik, Croatia
The jewel of the tunnelling calendar heads to the Dalmatian Coast for the technical event of 2015 as WTC returns to Europe. Many details are yet to be confirmed, and the website is still under construction, but watch this space.
wtc2015.com

British Tunnelling Society

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

Thames Tideway Tunnels
19 September 2013
After more than two years of public consultation on Thames Water's proposals, the development consent application was submitted to the Planning Inspectorate on 28 February. The presentation will include back

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

Port Maine Tunnel
23 November 2013
Contingencies for a high pressure EPB tunnel under a river, presented by Steve Skelhorn.

National grid cable tunnels
21 December 2013
A report on the project, which comprises 33km of 3m and 4m diameter tunnels across London. John Trounson, National Grid Stephen Meadowcroft, Costain will present an overview of the business case for the project and details of the progress made.

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