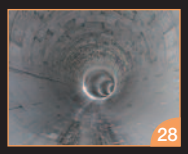
SEPTEMBER 2010

tunnels & tunnelling INTERNATIONAL



Special report: Great Britain
T&TI looks at what's keeping British tunnellers busy and pays a vist to Brighton's new sewer project

Technical: Ground improvement
T&TI looks at the latest in pre-excavation ground treatment solutions

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Driving under the Dorchester

A look at works to link the prestigious Dorchester Hotel and it's new annex

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Finding hope for Crossrail

The delays that hit Crossrail last month will leave the industry feeling nervous about what is to come. Awarding of the two main tunnelling contracts, C300 and C305, have been delayed until after the Government's Comprehensive Spending Review next month. Crossrail has now said it will award the contracts early next year and also claimed the delay in awarding the contracts will not delay the start of construction (see page 5).

The two running-tunnel contracts are the highest value contracts on the project and will pump a lot of much needed work into the British tunnelling market. However, postponing the contract awards until after the spending review is leading many to fear that project may not survive the chopping block.

T&TI broke the story online and immediately called round to the companies bidding for the work. We were amazed that none of the bidders we spoke with had had notice from Crossrail of the delay. But the bidders were not surprised by the news, which must be telling of the atmosphere in the Crossrail offices ahead of the review.

There is still a lot of hope in the industry, and rightly so. The project has had cross-party backing, especially since it became a hot topic in the General Election earlier this year. And last minute reviews of major projects are commonplace. It happened on the Jubilee Line Extension and on the Channel Tunnel Rail Link. (CTRL).

On CTRL the review led to the project being broken into two phases. The first phase from Cheriton to north Kent went pretty much as planned, but included only limited tunnelling. The majority of the second phase was tunnelled to bring the high-speed line to St.Pancras in north central London.

There is scope to do the same with Crossrail. The main running tunnels crossing London could be broken into a phase one with the major station upgrades. And the spurs and additional stations could be broken into a second phase. This would give the industry the injection in needs and help tackle the east-west congestion in London while also cutting back on some of the project cost in the short term.

There remains the risk that the project will go sour. Many people in the industry claim far too much has been invested in the project to date to back out. And while the logic works, in practice anything could happen. Again the Channel Tunnel has a precedent on this. In 1974 work began on a state-funded crossing but a change of government led to the cancellation of the project in 1975 after some 300m had been bored from the British side. It was not until 1988 that work on the project started again.

Jon Young

contents

On the cover

T&TI looks at the tunnel connecting prestigious London hotel, The Dorchester, with its new annex building

NEXT MONTH:

In the next issue *T&TI* will be looking at tunnelling activity in southern Europe. And in the technical pages we'll look at tunnel user safety and rescue systems.

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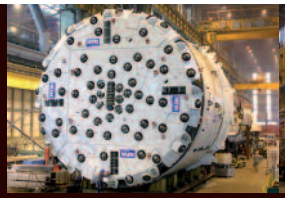

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Crossrail delay triggers cut fears

GREAT BRITAIN

Crossrail has delayed awarding the two main tunnelling contracts by at least half a year, sparking fears of drastic changes in the project scope. The contracts were to be awarded in mid 2010 but *T&TI* has learnt they will not be awarded until next year, after the government's Comprehensive Spending Review in late October. A Crossrail spokesman said the delay would not postpone the start of tunnelling works.

Crossrail spokesman Ankeeta Munsi said, "bids for two of the tunnelling contracts have been submitted and are being evaluated. It is the current intention to award in 2011. The mid 2010 date was always an indicative date. Tunnelling construction activity will get underway in 2011 as planned."

Bidders for the project told *T&TI* that the news was disappointing but not surprising. The government Comprehensive Spending Review will be published 20 October 2010 and will set out spending plans for the years 2011-12 to 2014-15.

The spokesman for one contract bidder said, "the whole industry is worried about what will happen come October. We knew it was unlikely [the contracts would be awarded on time] but we are now hoping the project scope will not be changed too drastically."

Bidders are in the dark on how the project will move forward. The spokesman for one bidder said if the delay in awarding the contracts is a result of the spending review the industry will know by the end of the year. "It is now official that we won't have packages before 2011 but we don't know much more."

The delayed contracts are C300 and C305.

C300, also known as Tunnels West, comprises the construction of twin 6.2m diameter bores running 6.2km from Royal Oak to Farringdon Station.

C305, known as Tunnels East, comprises three tunnel lengths. The major part of the contract is the twin 6.2m diameter bored tunnels from the Limmo Peninsular through to Farringdon Station, with a total length of 8.3km. Next is the 2.7km drive from Stepney Green through to the Pudding Mill Lane portal. Finally is the 0.9km drive from the Limmo Peninsular through to the Victoria Dock portal.

Dams to be interconnected in northern India

INDIA

The state irrigation department of Maharashtra, India has proposed a plan to interconnect dams in the state to help solve the problem of water shortage and to increase irrigation potential in the region.

The project, proposed by Avinash Surve, superintending engineer of Pune Irrigation Circle, includes digging a tunnel towards the bottom that will release the full reservoir level water of the Panshet dam into the Varasgaon dam. The sharply inclined tunnel will restrict the water from flowing back to Varasgaon. Surve reportedly stated that digging the tunnel is very critical, as the mountain range between the two dams is not even 400m wide.

The second proposal to release water from Gunjawani dam into Bhatghar dam is easier and more likely to get the nod from the state government. The partially completed dam currently stores 0.69M cubic metres water but will have the capacity to store 3.69M cubic metres after the dam work is completed.

Panama takes delivery of TBM

PANAMA

The TBM that will bore the 8km long interceptor tunnel for the Panama City Wastewater Treatment Plant was delivered to Manzanillo, Colon on 24 August.

The Herrenknecht utility tunnelling machine M-1494M EPB-Shield is 107m long and has a 3.67m outer diameter. Contractor Construtora Norberto Odebrecht (CNO) is constructing the tunnel, which will collect the capital city's water and convey it to the new processing plant.

Named Gloria, after the mother of Panama's president, Ricardo Alberto Martinelli Berrocal, the TBM has 26 disc cutters, each 13 inches, and is scheduled to run 24 hours a day. The tunnel will be constructed with a segmental lining.

The Interamerican Development Bank loaned the Panamanian Ministry of Health USD 45M for the project because of its efforts to decrease levels of contamination in Panama City's bodies of water. Nippon Koei of Japan has provided feasibility studies and developed basic engineering for the scheme.

Below: TBM 'Gloria' arrived in Panama for the 8km inceptor tunnel

Hotel to be moved for tunnel

NEW ZEALAND

A 125-year-old hotel will soon be lifted from its base and moved to a temporary location to facilitate excavation work at the new Victoria Park Tunnel in Auckland, New Zealand. The project is part of motorway extensions taking place in the city.

The Birdcage, built in 1885 as the Rob Roy Hotel, will be jacked up, put on concrete beams and moved 40m up Franklin Road. Upon completion of the work in about six months time, the hotel will be moved back onto its original site on top of the new tunnel and become part of a new plaza.

Helen Cook, a member of the Victoria Park Alliance, told local reporters that the sifting process is expected to take about six to 10 hours. The 450m long Victoria Park Tunnel Project is one of the seven roads of national significance. Construction of the tunnel will eliminate the last serious traffic bottleneck on the central motorway junction between the Auckland Harbour Bridge and the Newmarket Viaduct. The tunnel will take three northbound traffic lanes, and the existing Victoria Park viaduct will be reconfigured to carry four southbound lanes.

Above: The 125-year old Birdcage being jacked up ahead of its 40m move to make way for the new Victoria Park Tunnel

News in brief

Construction kicks off
Joint venture Southland Contracting and Tutor Perini Corporation started construction on 26 August for the New Irving Tunnel project in San Francisco at two shaft locations. The 3.5 mile (5.6km) tunnel will have an internal diameter of approximately 8.5 to 10.5ft and will be a seismically-sound connection for water distribution, owned by the San Francisco Public Utilities Commission.

Dublin Port Tunnel reaches settlement

IRELAND

Dublin City Council last month settled a legal claim from the Nishimatsu/Mowlem/Irishenco joint venture (NMI) that built Dublin Port Tunnel. NMI had sought the extra payment for additional costs associated with the completion of the 4.5km route, including the resolution of leaks.

The settlement brought the final cost of the tunnel to EUR 789M (USD 1bn). The claim was settled for EUR 37M (USD 47.4M), bringing the final construction cost to EUR 639M (USD 819M).

When the EUR 100M (USD 126M) spent on acquiring land and EUR 50M (USD 64M) on planning, insurance, legal fees and related costs, are included the overall cost rises to EUR 789M (USD 1bn).

British company Carillion, which owns Mowlem, pursued the claim on behalf of NMI. The consortium's claim was considered by a review panel comprised of engineering experts appointed with the agreement of both sides. The panel made recommendations, which were accepted.

A spokesman for the National Roads Authority, which was a notice party to the case because of its role as the funding agent, said in a statement that the claim had come to an "appropriate conclusion."

The twin-bore tunnel opened in December 2006 following a six-year build. It was designed to bring heavy goods traffic from the M1 motorway to Dublin Port while avoiding the city centre.

Panel to review HS2 compensation claims

GREAT BRITAIN

An independent panel will decide on compensation claims made by householders affected by the planned HS2 link between London and Birmingham. Under the Exceptional Hardship Scheme, the panel will review claims on a case-by-case basis. The Government will then buy homes and business properties affected by their proximity to HS2.

The offer applies only to properties on the preferred route of the HS2 track—which leaves London via Ruislip and passes near Amersham, Wendover and Aylesbury before approaching Birmingham between Coventry and Kenilworth—and not for the two alternative routes.

Those that wish to claim will have to show that their property has been on the market for at least three months and has failed to attract any offers above 85 per cent of its value before the route was announced in March.

The Exceptional Hardship Scheme is intended to ensure that "people who currently are faced with extreme hardship as a result of the identification of that route have the possibility of being able to sell their properties, notwithstanding the inevitable planning blight," said transport secretary Philip Hammond.

Sandy begins work on Airport Link

AUSTRALIA

The second TBM on Brisbane's Airport Link project has started tunnelling from the Kalinga Park worksite, premier Anna Bligh announced last month. The machine has been named Sandy.

That means Australia's two largest TBMs will be hard at work with Sandy's sister Rocksy tunnelling more than 70m and installing 32 completed rings to construct the tunnel lining since her launch a month ago.

Bligh said at the half-way point of the project's construction programme and spend, it was great to see so many milestones being reached across the project.

"To date, over 10 million hours have been worked and the projects have surpassed their expected peak employment by an additional 800 workers bringing the jobs total to 3,400," she said.

"Across the project more than 5km of Airport Link tunnelling is now complete and within the next 24 hours Sandy will begin her 2.5km journey from Kalinga Park to Lutwyche, excavating the westbound mainline Airport Link tunnel.

"The scale of this project is incredible. The TBMs alone are the largest of their type ever to operate in Australia and they are working on the largest road tunnel project in our history. I wish the tunnellers a very safe journey to Lutwyche," she said.

Minister for infrastructure and planning Stirling Hinchliffe said Rocksy and Sandy will operate 24 hours a day, seven days a week over the next 12 months.

Above: Aerial view of the jobsite. The TBMs have been launched from the green shed in the right of the picture

"Spoil from the machines will be transported to a handling facility at Nudgee Road by a 1.8km conveyor system which will remove up to 80,000 spoil truck movements from local streets," he said.

"Extensive monitoring of the ground conditions, vibration and noise will be carried out during excavation to try to limit the disruption caused by this vitally important project as much as possible.

"Residents will receive direct notification two weeks prior to the TBMs approaching their property and the projects community relations team will also be conducting regular information as tunnelling progresses."

Thiess John Holland project director Gordon Ralph said Rocksy still has a way to go before the rear of the machine is attached.

"Because the machines are 195m long they have to be launched in two stages. Once Rocksy and Sandy have excavated 130m they will stop for six weeks so the rear of the machine can be assembled," he said. "Once final assembly is complete, Rocksy and Sandy will begin work again, excavating the tunnel and progressively installing concrete segments to form the tunnel lining moving forward up to 85m per week."

CEO of BrisConnections Ray Wilson congratulated the team on the launch of the second TBM.

"Today's launch brings our team one step closer to the operation of the Airport Link in June 2012. With the project now more than 50 per cent complete, construction is progressing well on all work fronts," Wilson said.

By mid-2012, Airport Link, in conjunction with the Airport Roundabout Upgrade, will remove up to 18 sets of traffic lights for motorists travelling from the city to Brisbane Airport and Australia Trade Coast, reducing travel time by up to 50 per cent.

The Airport Link project is being constructed together with the Northern Busway (Windsor to Kedron), and the Airport Roundabout Upgrade Project. The combined Airport Link projects are the largest road infrastructure projects currently under construction in Australia.

Sochi tunnel construction underway

RUSSIA

The Russian government will go ahead with plans regarding the construction of transport infrastructure in Sochi, which will host the Winter Olympics in 2014.

Several tunnels will be built as part of the project, with a total length of 26.5km, of which 10.3km will be railway tunnels, 6.7km road and 9.5km shaft tunnels. In total 10 tunnels will be built.

Anatoli Babinez, the official representative of Stroy-Trust, the contractor responsible for the project, said in a statement that construction of all 10 tunnels is currently underway using drill and blast method.

He added that the company had already completed tunneling the shortest railway tunnel on the combined road connecting Adler and Alpika-Service mountain resort in Sochi.

Total cost is estimated to be RUB 270bn (USD 8.8bn).

Lake Mead tunnelling delayed

USA

Tunnelling for the third water intake at the Lake Mead reservoir in Las Vegas has been delayed after workers hit a pocket of water under the lake in early July.

Over a period of four days inflow from a pocket of loose material behind the face of the starter tunnel entered the area and the assembly chamber. Since then the inflow has been mucked out and the project is working to re-establish the face of the starter tunnel.

Following the May delivery of a 6.36km diameter Herrenknecht TBM to bore the 4.83km tunnel, the project had anticipated starting tunnelling in July.

Robin Rockey of the Southern Nevada Water Authority (SNWA) said this is an on-going issue because work is being done 600ft (183m) below surface, and there is a lot of thermal activity.

"Water comes in from thermal pockets at 90 degrees Fahrenheit," she said. "There are a lot of fissures and cracks in the rock. Water comes in sometimes at 400 gallons per minute and sometimes up to 700 gallons a minute. It's been constant."

The USD 447M design/build contract for the project was awarded to Vegas Tunnel Constructors, a joint venture consisting of Lombard, S. A Healy and Impreglio.

SNWA is uncertain when tunnelling will start and how much time the inflow has cost the project.

"We're really optimistic that it won't change the completion date of 2013," Rockey said.

Left: Front shield pieces of the TBM are ready to be lowered into the assembly chamber at Lake Mead

News in brief

Hindhead sets 2011 open day walk through

Hindhead Together announced the 1.8km long A3 Tunnel will open to the community on 14 May 2011 prior to its official traffic opening later that summer. The GBP 371M (USD 571M) project will link London to Portsmouth bypassing the Devil's Punch Bowl, a site of scientific interest.

Mumbai Twin tunnels near completion

Construction is almost complete on 450m twin tunnels being built as part of the four-lane Eastern Freeway project in Mumbai. Mumbai Metropolitan Region Development Authority (MMRDA) spokesman Dilip Kawathkar stated 350m of the left tunnel and 250m of the right tunnel have been excavated and soon a cross section of 100m in both tunnels will be concreted. Estimated to cost INR 610M (USD 13M), they are the city's first twin tunnels.

Budapest Metro Line 4 reaches milestone

HUNGARY

Work on Budapest's new Metro Line 4 reached a key milestone last month with the breakthrough of both TBMs at Keleti Station. This completes the two running tunnels of the line from Kelenfold Station to Keleti.

The 7.3km long first phase of the Line 4 underground system will include 10 stations and will connect with the existing Metro Lines 2 and 3 and the main line railway network at both Kelenfold and Keleti.

British consultant company Mott MacDonald was serving as part of the design consortium. This involved preparing tender documents for the proposed design and build contracts as well as updating the 1998 Railway Approval Design to include alignment improvements and further architectural development. In addition, the company provided specialist input on tunnelling methods specifications and designed the ventilation system for the project using in-house modelling software.

Mott MacDonald also completed the detailed design for the sprayed concrete lined (SCL) tunnel at Bocskai Station and provided expert advice on settlement, SCL design and the underpassing of the river Danube.

Swietelsky also appointed Mott MacDonald as environment consultant for the project, responsible for noise and vibration impact assessments for interior construction work at all ten stations along the new line.

Alun Thomas, Mott MacDonald's deputy manager in Budapest said, "we are delighted to be working on this project. In terms of technical achievement, this is a proud moment for us."

Leinster house to get tunnel

IRELAND

Construction of an underground link at Leinster House, the building that houses the Oireachtas, the national parliament of Ireland, was approved last month.

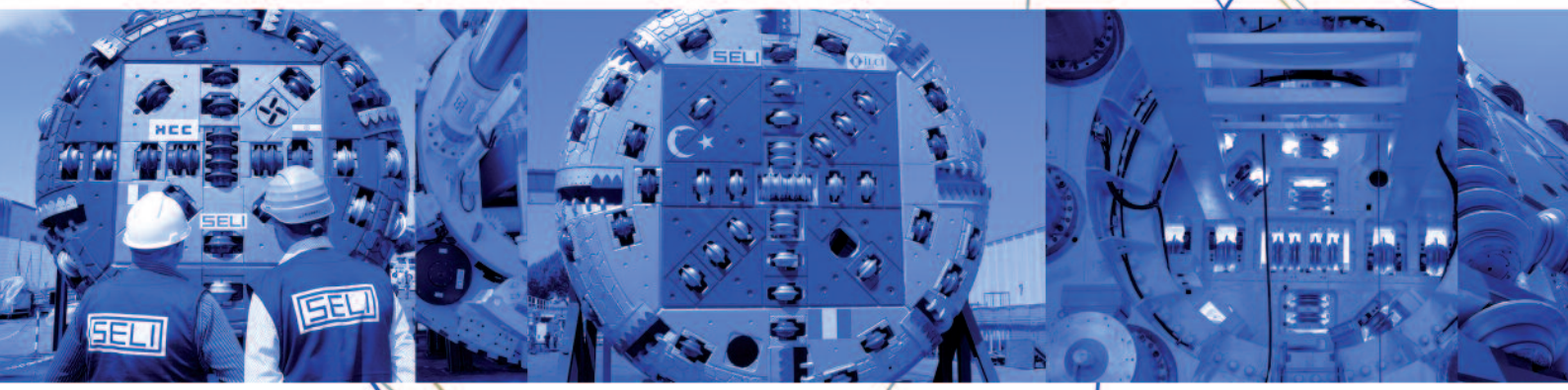
The project's estimated cost has been stated to be EUR 1M (USD 1.28M). The Office of Public Works made the announcement, stating that Dublin City Council and the Department of Environment would be moving forward with the project since the public made no objections.

The Leinster House campus will be connected to the Department of Agriculture headquarters down the street, with the help of an underground corridor.

The project is slated to save an annual sum of EUR 700,000 (USD 897,492) in office space rent. Scheduled for completion in two years' time, the tunnel should cover the cost of its construction within less than 18 months.

Leinster House will also be made disability-compliant by the end of 2011. Additional work on the building will reach completion within a period of two years.

Boring through future



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NZTA has plans for Homer Road

NEW ZEALAND

The Homer Road Tunnel in New Zealand has received an ambitious construction proposal from the New Zealand Transport Agency (NZTA).

NZTA has proposed construction of a new tunnel beside the old Homer Tunnel or the expansion of the present tunnel to make it wider.

The NZTA hopes to improve safety of the road tunnel that serves the Fiordland region New Zealand's South Island.

A widening of the tunnel, to allow for true two-laning, has also been a topic of discussion. This would be unlikely due to high costs though.

NZTA regional director, Bruce Richards, said that a tender process for the design of any chosen upgrade will be carried out after October 2010. He added that the funding still needed to be allocated. Richards also indicated that work on the tunnel could begin within the next financial year. Work on the Homer Tunnel project would cost around NZD14M to 15M (USD 10M to 10.7M).

The Homer Tunnel runs beneath the Homer Saddle within Fiordland National Park. The 1.27km long tunnel has a 10 per cent gradient and varies in width from 6.5m to 7.5m. At the height of the summer tourism season it is used by more than 100 tour buses a day.

Thu Thiem Tunnel nears completion

VIETNAM

Construction work on the immersed tube Thu Thiem Tunnel under the Sai Gon River in Vietnam is nearing completion.

The East–West Highway and Water Environment Project Management Board and Japan-based contractor Obayashi began pouring concrete to connect the fourth section with the final section on the District 1 side earlier this month.

The fourth section was sunk into the river on 5 June after being delivered from Nhon Trach District in neighboring Dong Nai Province, where all the sections were fabricated.

The tunnel is due for completion on 2 September and should be connected with the completed East–West Highway in January 2011.

Thu Thiem Tunnel joins Ho Chi Minh City's Districts 1 and 2.

News in brief

Tunnel proposed in Kashmir State

India's Ministry of Defence is considering a tunnel at the 3,505m Zojila Pass on the Srinagar-Leh road. Defence minister AK Antony said a consultantcy contract has been awarded with a 18 month time frame.

Construction resumes on Nepal's Melamchi Tunnel

NEPAL

The Melamchi Drinking Water Project in Kathmandu, Nepal saw construction work resume last month on the Sundarijal side.

Two Chinese companies, China Railway 15 Bureau Group and China CMIIC Engineering, were awarded the contract to construct the 26.5km long diversion tunnel connecting Melamchi River with Sundarijal in Kathmandu.

Locals stalled construction work after complaining that their houses suffered cracks due to the blasting in Mahankal of Sundarijal VDC-7. Work resumed on 17 August after a three-party meeting between local residents, Melamchi Drinking Water Project and contractor China 15 Railway.

According to the agreement, residents of Surya Lama and Chhiring Lama will be temporarily relocated.

The project will bear all the costs of relocation and will also repair the damaged houses after completion of the tunnel. Some 96m of tunnel has so far been constructed.

The construction of the tunnel has been disrupted three times since its inauguration on 3 August 2009. The project aims to bring 170 million litres of water to the Kathmandu Valley every day. The government of Nepal contributed 20 per cent and the Asian Development Bank provided 80 per cent loan assistance for the tunnel's construction. The Melamchi project was initially scheduled for completion by 2013.

North Shore City tunnel officially opened

NEW ZEALAND

A new NZD 116M (USD 81M) wastewater tunnel and outfall opened officially last month in North Shore City, New Zealand. The scheme is the city's largest infrastructure project, and a key part of a long running council project to improve water quality at the city's beaches.

The tunnel and outfall replaces a pipeline built in 1958 that carried treated effluent from Rosedale Wastewater Treatment Plant and discharged it just 600m offshore from Castor Bay. The treated effluent is now deposited much further out to sea.

Construction on the 3km tunnel took contractor McConnell Dowell 10 months and started in February 2009. The tunnel was bored by TBM. The shell of the boring machine remains deep inside the tunnel because of problems getting it out.

The council said the tunnel and outfall have a lifespan of at least 100 years and will cater for the city's continued growth.

The 2.1km outfall pipe, constructed by joining 12m lengths of pipe, was fabricated in Kaiaua on the Firth of Thames. Each section, 400m to 500m long, was individually towed by tugboats about 100km to Mairangi Bay. After the pipeline was installed divers attached 58 diffuser nozzles, to disperse the treated effluent through last 350m of pipeline. The final stage of the project saw 24 concrete segments, each weighing 56t, installed to connect the treatment plant to the tunnel entrance. Following successful tests in mid-July the tunnel and outfall are in full use.

Treated wastewater travels 3km underground from the Rosedale plant to Mairangi Bay and then 2.1km offshore where it is dispersed deep in the Rangitoto Channel.

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USS joins HS1 bidding

BIDS

The Universities Superannuation Scheme (USS) has joined the GB Speedrail Group joint venture bidding for High Speed 1, which links London to the Channel Tunnel. The British Government is selling the link in an attempt to cut the country's budget deficit. It is valued at GBP 1.5bn (USD 2.3bn).

A GB Speedrail Group spokesman confirmed USS involvement, naming the four remaining partners as CDC Infrastructure of France, Goldman Sachs Infrastructure Partners, M&G's Infracapital and the company currently responsible for operating the railway infrastructure Eurotunnel. The USS brought "important retail investment experience to the bid," added the spokesman.

USS is not the only pension fund reported to be involved in the bid. Reports suggested that Canada's Ontario Municipal Employees Retirement System (OMERS) is partnering with the Ontario Teacher's Pension Plan through Borealis, the OMERS infrastructure investment arm, in a separate offer.

Leighton Asia awarded XRL contract

CONTRACT AWARD

MTR Corporation has awarded the Leighton Asia/Gammon joint venture the USD 371M contract to construct the West Kowloon Terminus Approach Tunnel and Track Fan Tunnel section of the Guangzhou-Shenzhen–Hong Kong Express Rail Link (XRL).

This is the second XRL project contract to be awarded to Leighton Asia following the award of an AUD 463M (USD 417.2M) contract in March this year for the construction of tunnels and a ventilation building in the Tse Uk Tsuen to Shek Yam section.

The latest contract includes the construction of a 31m wide approach tunnel and 121m wide track fan tunnel, as well as a public transport interchange incorporating associated buildings and landscaping. Other works include the construction of 300m road underpass and two new footbridges.

Leighton Asia Managing Director Hamish Tyrwhitt said, "The award of this contract by the MTR Corporation demonstrates Leighton Asia's ability to deliver outstanding results for its clients."

He continued, "Upon completion, the XRL will greatly enhance accessibility between Hong Kong and mainland China, further strengthening the social and economic development and we are excited to be playing a key role in this effort to provide a fast and convenient railway service to the communities."

Contract works will start this month with completion scheduled for 2015.

Seli and Kawasaki extend partnership

COMPANY

Seli and Kawasaki Heavy Industries signed an extension of the previous Collaboration Agreement on 2 August.

Both companies stated that projects, which will take place in Spain and Portugal and which were excluded from the previous agreement, will be included in the potential projects of Seli carried out on an exclusive basis.

In accordance with the agreement of 15 April, 2010 Seli and Kawasaki will combine resources and experience in engineering and manufacturing as well as on-field service and operation of TBMs and focus on EPB type TBMs of all sizes, on upcoming projects in Europe and North/Latin American countries.

XRL awards Contract 824

CONTRACT AWARD

The Kier/Kaden/Ossa joint venture will construct by drill and blast about 3km of tunnel between Ngau Tam Mei and Tai Kong Po on the Guangzhou-Shenzhen-Hong Kong Express Rail Link. The HKD 1.5bn (USD 194.8M) contract 824 was awarded by Hong Kong's MTR Corporation.

Contract 823B, the final major tunnelling contract on the project, will be awarded in October. It involves work on the Shek Kong Stabling Siding.

The whole USD 8.3bn project is scheduled for completion in 2015. Once complete, passengers will be able to travel from Hong Kong to Shanghai in eight hours and Beijing in 10. Currently the journey takes 20 hours.

News in brief

Normet starts spare parts centre in Netherlands
Normet has announced the opening of its global distribution centre for spare parts in Maarssen, the Netherlands. Growth of the company's Life Time Care business was the main reason for the new spare parts operations, will be run by Normet International of Switzerland.

Spain seeks rail bids
An open invitation to tender for the 2.78km Andoain-Urnieta section of high-speed rail including one tunnel and two viaducts is due 30 September to the Gobierno Vasco. The contract covers track construction works, railway tunnel work and reinforced-concrete structures.

Call for advisory services on Thames Tunnel
Thames Water is looking for expressions of interest from organisations to qualify for upcoming contracts regarding legal, financial and commerical advisery services. The successful bidder or bidders will assist in developing a new delievery model for the proposed 30km long Thames Tunnel, based on the Flood and Water Management Act of April 2010.

Shetland approves manager role for project
The infrastructure committee of the Shetland Islands Council has voted to take on a senior manager to push ahead with the council's GBP 300M (USD 461M) plan for four subsea tunnels to the main islands over the next 20 years. Fear of depopulation had encouraged the position, despite the fact that a source of funding is still unknown.

Strabag marks record order backlog

ANNUAL REPORT

Austrian construction company Strabag announced a record order backlog of EUR 15.75bn (USD 20.21bn) when it released its semi-annual figures on 31 August.

Strabag attributes the 10 per cent increase over that of June last year partly to newly acquired large-scale projects in the Polish transportation infrastructure segment. While full consolidation of railway construction subsidiary Viamont in Slovakia during the first quarter of 2010 also had a positive effect on the order backlog.

"We are also seeing the results of our plans to grow in Northern Europe and in non-European markets," CEO Hans Peter Haselsteiner said. Strabag is working to expand its market presence in the Benelux countries and Scandinavia.

Output volume in the first quarter of the year was down due to winter weather and the completion of several large Middle East projects. This drop was not compensated later in the second quarter, and Strabag at EUR 5.2bn (USD 6.7bn), is 7 per cent below the first six months last year.

Despite the decrease Haselsteiner said Strabag's full year outlook remains stable. "We are well on our way to concluding the current financial year with output volume and results at the previous year's levels."

Atkins acquires PBSJ

TAKEOVER

UK consultant Atkins announced its intent to acquire Florida-based engineering, design and construction management firm PBSJ for USD 280M, with the deal expected to close early this autumn.

Once the transaction is completed, PBSJ will operate as a national business of Atkins in the US and will be led by its current CEO, Robert Paulsen, reporting directly to Atkins's chief executive, Keith Clarke.

One of the reasons for the sale of PBSJ had been the firm's struggle to grow because of its employee ownership scheme, said Paulsen.

He told the *Tampa Bay Business Journal*, changing work force demographics prevented expansion because the capital it receives through the employee ownership has been difficult to maintain as baby boomers retire and younger workers aren't as likely to invest.

The transaction is subject to approval by PBSJ's shareholders and standard closing conditions, including regulatory approvals. PBSJ's Board of Directors unanimously approved the agreement and recommended that

Brisbane toll road tanks

LOSS

RiverCity Motorway Group, owner and operator of Brisbane's Clem Jones Tunnel (CLEM7), posted an AUD 1.67bn (USD 1.52bn) loss primarily due to an AUD 1.56M (USD 1.42M) impairment write down of the CLEM7, resulting in an intangible asset value of about AUD 250M (USD 227M).

The 6.8km tollway links five major roads and includes twin, two–lane 4.8km tunnels, bypassing the city's business district. Opening seven months ahead of schedule this March, the toll road has experienced traffic volumes well below the original forecast of 60,451 average daily trips one month after opening.

In May CLEM7 saw 21,424 average daily trips and during 1-29 August it saw the highest number yet with 27,908—though with tolls discounted by 50 per cent. Traffic growth is also well below what is required to meet the forecast of 100,284 average daily trips at the end of the 18 month ramp-up period.

Robert Morris, RiverCity chairman, called the situation serious and said, "current traffic will need to improve markedly over the coming months for the group to be in a position to meet its ongoing financial obligations after its existing cash reserves are utilized."

As of 30 June, the group had access to cash reserves of approximately AUD 127M (USD 116M) after the draw down of AUD 30M (USD 26M)in cash since opening. The balance of operational cash reserves as of 27 August was AUD 106M, having drawn down a further AUD 10.8M (USD 9.8M) and AUD 10M for July and August respectively.

Currently, precise reasons for the reduced traffic are unknown. In May, RiverCity appointed Integrated Management Information Systems to complete an assessment on traffic volumes in the tunnel, which is due at the end of the year.

Morris said the expected opening of the adjoining Airport Link tunnel in 2012 will significantly improve the traffic on CLEM7.

Shortlist for tunnel refurb, portal

CONTRACTS

Crossrail confirmed the shortlist for two contracts on 2 September, one for the refurbishment of the Connaught Tunnel and one for constructing the Pudding Mill Lane Tunnel portal.

Shortlisted for contract 315 for the Connaught Tunnel are Vinci Construction UK; Hochtief Murphy joint venture; Bam Nuttall; and VolkerFitzpatrick Barhale joint venture. The approximately 550m long tunnel runs between Royal Victoria Dock and Royal Albert Dock, and will need to be enlarged to accommodate Crossrail trains. About 100m of tunnel wall will need to be replaced with a new lining and other parts will be retained and repaired.

For contract 350 for the tunnel portal at Pudding Mill Lane, the shortlist includes Vinci Construction UK; Carillion Construction; Dragados-Sisk Joint Venture and Morgan Sindall.

The other tunnel portal will be located at Royal Oak, where prep work started in January for a 190m diaphragm walled box to form the foundation for a TBM launch.

The invitation to tender for contracts 315 and 350 will be issued in October, and Crossrail said it intends to award them both in 2011.

City at loggerheads over proposed tunnel

OTTAWA LIGHT-RAIL TUNNEL

Fierce debate is taking place in the Canadian city of Ottawa over a proposed light-rail tunnel (see *T&TI* February p9), with city councillors still at odds over the affordability and necessity the project. And with the city set to go to mayoral election in October this year, the topic has become one of the main campaign subjects on all sides.

The Canadian province of Ontario recently approved an environmental assessment on the multi-billion Ottawa light-rail tunnel (LRT) project.

The city's director of rail implementation, John Jensen, stated in a memo that the provincial environment ministry had approved LRT's environmental assessment, which examined the potential impact of a 12km light-rail transit line from Tunney's Pasture to Blair Station, including a 3km tunnel through the centre of the city to the University of Ottawa.

The total cost of the light-rail project is CAD 2.1bn (USD 2bn), of which the provincial and federal government would contribute CAD1.2bn (USD 1.16bn), while the city will have to raise at least CAD 900M (USD 872M). The city is now obtaining engineering design bids for the rail line, tunnel and stations.

However, there remains doubt in some corners as to whether this is the best route for the city to take.

Mayoral candidate Jim Watson has publicly fretted about the CAD 735M (USD 713.9M) estimated cost of the tunnel, and councillor and mayoral candidate Clive Doucet has said the tunnel should be scrapped in favour of rail line along Carling Avenue. Doucet told *T&TI* at the start of this debate that he couldn't understand how the council could budget for the first stage of the tunnel when "we can't even afford a universal pass for students that will cost CAD 200,000 (USD 191,600) and we're cutting bus lines." Doucet has not changed his mind about the project.

However, Bay councillor and mayoral candidate Alex Cullen last month hit back at those questioning the need for a tunnel, saying a significant change to the project would mean redoing the environmental assessment, plus more public consultation and background studies—something that took council four years to complete for its current project. Cullen said in response to questions over the potential cost of the tunnel, "for all intents and purposes, the tunnel debate is dead, because your other choice is to restart the whole process."

Deputy city manager Nancy Schepers, who is in charge of transit, agreed with Cullen. Pulling out of the tunnel option would mean the city would have to "go back to the drawing board on its transit plan," she said.

Schepers added that, "looking at another option, such as surface light-rail, would require figuring out how the system would work with different traffic volumes. That's a lot of hard work."

The Tunney's Pasture-Blair Road project is the first phase of a larger, CAD 5.6bn (USD 5.42bn) transit master plan that has been split into two parts to be completed over the next two decades.

The first phase, costing about CAD 3.7bn (USD 3.58bn), is itself divided into three parts—the CAD 2.1bn (USD 2bn) Tunney's-Blair line, which will be completed by 2018 and become operational in 2019; a second phase that includes extending a rail line from Tunney's Pasture to Baseline Station subject to the availability of funds; and a third line from Bayview to South Keys that will replace the existing diesel O-Train with electric rail. The latter two projects are estimated to cost about CAD 1bn (USD 969M) each.

Cullen said a procurement report will be completed next year. He said, "the risk of any cost change does rest with the City of Ottawa, and obviously, city council will be looking very closely at the procurement process and its options in terms of controlling those costs."

Not so revolutionary

Dear Sir,

I refer to the article in T&TI July 2010 (pp41-42 'Segment fibre reinforcement in Barcelona') and am surprised that the use of steel fibre reinforcement only is considered as 'a revolutionary step' by the writer.

I was privileged to work on the CTRL tunnels for the Project Representative team and was closely involved with both the contractors and the project/design team, led by the very competent Eddie Woods.
All the main tunnel segments for these 7.15m. i.d. tunnels were pre-cast concrete fibre-reinforced units also incorporating polypropylene fibres for fire resistance and to the best of my knowledge continue to perform well in the tunnels.

I accept that the Barcelona tunnels are a greater diameter but this technology was adopted on the (very successful) CTRL project in the late '90s and successfully manufactured and installed at the start of the 2000s, so it is hardly 'revolutionary' in 2004 or later!

I fear that this misapprehension yet again demonstrates that our industry is very poor at exchanging technical information and does not adopt 'lessons learnt' very readily.

I recall that there was a full and excellent presentation of this technology presented to the BTS by Woods, Davies et al several years ago, so it is most certainly in the public domain.

Neville Harrison CEng, *FICE*

Left: Precast lining segments with steel reinforcement fibres in the Barcelona Metro

Britain's got tunnels

With water projects underway, the industry has Crossrail on the brain and for good reason, it sets the tone for the future of tunnelling in the UK, reports Nicole Robinson

Boasting a total budget of GBP 15.9bn (USD 24.6) and 42km of new tunnels, it's no surprise the tunnelling industry in the UK is waiting with baited breath for Crossrail. It's regarded as a major lifeline for the UK tunnelling industry, even sparking conversations about skilled worker shortages, though it's uncertain exactly how much of and how fast the massive rail expansion will move forward (page 5). In the meantime, other major schemes are still in contemplation or under review, such as High Speed 2 (HS2) and Thames Water's Thames Tunnel. While the recession has tightened client's budgets, and government spending is under review, there is still work to be found in the UK.

The Crossrail project intends to expand rail services through and under London to Maidenhead and Heathrow in the west, and Shenfield and Abbey Wood in the east (page 18). In addition to 21km of twin bore tunnels, eight new central London stations will be built and 28 existing stations will see upgrades. There is an enormous number of design engineers employed on Crossrail at this point, but very few contractors, says Helen Nattrass of the BTS' Parliamentary Lobby Group. And those contractors that are employed are working on demolition and diversion of cables and pipes, not tunnelling.

Work has started in areas like the new ticket hall at Farringdon Station. Contracts have gone also out for station work including one for GBP 500M (USD 770M) for the redevelopment of Tottenham Court Road Tube station, and another worth GBP 700M (USD 1.08bn) for Victoria station—both to a joint venture of Taylor Woodrow Construction and BAM Nuttall Limited. A third contract worth GBP 130M (USD 200M) for Bond Street Tube station was awarded in early August to Costain Laing O'Rourke joint venture. Transport for London says the overall cost of Bond Street station's redevelopment will cost GBP 300M (USD 462M) when the project is completed in 2017.

Potential austerity measures would create another hurdle for Crossrail, not to mention the tunnelling industry at large. The coalition government, elected in May, has prioritised deficit reduction as its most urgent issue, and public sector spending is under scrutiny leading up to the 20 October publication of the Comprehensive Spending Review. This report outlines spending plans in the UK for the years 2011-12 to 2014-15.

Bob Ibell, chairman of the British Tunnelling Society, accepts the possibility that cuts in public spending could hit the industry resulting in projects not going ahead. "It would however be an absolute body blow to the UK tunnelling industry if Crossrail didn't happen," he says.

"Austerity measures undoubtedly will hit us. They will have an impact on wages and they may have an impact on employment in our industry." But he's cautiously optimistic that Crossrail will avoid the chopping block, because of the money already spent and because the project has achieved a lot of momentum. "I am sure however there will be some difficult decisions to be made there on scope, because the extent to which you can change the cost of doing the work once you've completed your design and started on site is very limited."

But prior to the coalition government's budgetary plans, and even their entrance into office, the industry had been quite tight. The amount of work being released has been significantly reduced from two years ago because of the recession, says Dickie Dexter, tunnelling director of Joseph Gallagher Limited. "I would expect to see more of the same, that private utility companies will tighten their budgets and will also make their budgets work a lot harder. It wouldn't be unusual three or four years ago, to see three or four people on a tender list whereas now you can easily see seven or eight."

For now, he says, most of the work is coming through water authorities doing pipe jacking and shafting. "The major schemes are great when they come along, but it's still a utilities business," he explains. "It's always going to be utilities because they're the largest long-term budget."

Work has kicked off on Southern Water's GBP 300M (USD 466M) environmental improvement scheme, which, among other improvements, includes building 11km of new sewer tunnels. These will transfer wastewater from Peacehaven, Telscombe, Saltdean, Rottingdean, Woodingdean, Brighton and Hove, to a new wastewater treatment works and outfall located at Peacehaven. The 4Delivery consortium comprising United Utilities, Costain and MWH is working with Southern Water to mine the tunnels and construct the treatment works at Peacehaven. Two TBMs with 2.44m internal diameters have been hired from Magnor Plant, the in-house plant hire company of Morgan Sindall, and were delivered in June (page 23). Tunnelling is underway with advance rate of 40m a day, and Southern Water hopes to increase that 60m for completion in February 2011.

Thames Water says it will start tunnelling on the 4 mile (6.4km) Lee Tunnel in late 2011. Part of the London Tideway scheme of improvements to stop sewer overflows and improve the River Thames, the Lee Tunnel will transfer sewage from Abbey Mills Pumping Station to Beckton Sewage Treatment Works. This should prevent more than 16 million tonnes of sewage mixed with rainwater from overflowing into the River Lee, a tributary of the Thames. A GBP 400M (USD 621M) contract to construct the tunnel was award in December 2009 to a

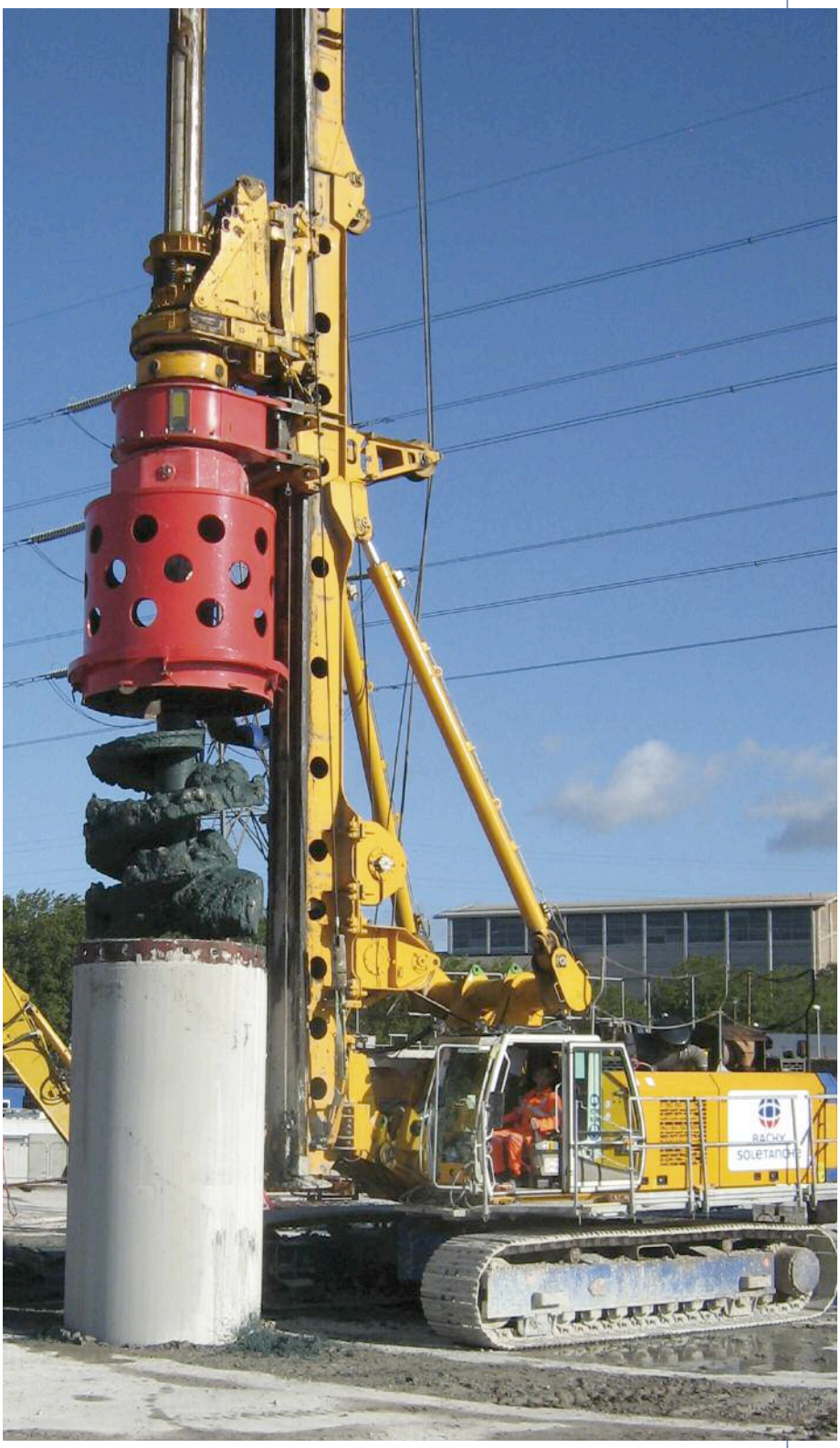
joint venture of Morgan Est, Vinci Construction Grands Projets and Bachy Soletanche (MVB). The tunnel, which will be 7m in diameter and as deep as 75m in some places, is scheduled for completion in 2014. To date, construction on the tunnel has only involved enabling works and site establishment. MVB is currently coring 80 holes around the circumference of the drive shaft to ensure no unexpected obstructions are encountered when construction of the diaphragm wall starts in September. Construction will start on the drive shaft and two other shafts this year.

It's the first of two planned tunnels to start construction. The proposed 20 mile (32km) Thames Tunnel would run west to east across London to Beckton preventing discharges from 34 Victorian overflow points along the Thames. Its precise route is yet to be determined, and a period of public consultation will start in September to include a review of the route and construction sites. Thames Water hopes to submit the planning application for the Thames Tunnel in 2012, and has provisionally scheduled construction to start in 2013 to finish in 2020.

The now uncertain timelines of Thames Tunnel and Crossrail will determine the future of the UK tunnelling industry, and whether skill shortages do exist. The further Crossrail progresses, there will be more demand for the industry, and the more likely that foreign labour will be required. If work for the Thames Tunnel runs concurrently with Crossrail, which is standing firm on its expectation that passenger services will be running by 2017, there will be a higher proportion of foreign engineering staff and workforce employed in the UK, explains Nattrass. "When Crossrail begins it should take up just about the whole of the UK tunnel workforce." Or she says, the Tideway project might start toward the end of Crossrail and there will be carryon for the tunnelling sector. It's just too early to tell.

Ibell says the skills shortage isn't as pressing a problem as originally perceived. This is partly because there are fewer projects, and starts have been staggered, but also because the industry is aware of the problem and has taken action. "I'll be honest, I was one of the first to say 'we have a problem' and we did. But it was a good wake-up call to plan how we could train and develop new entrants into the industry."

Looking toward the long-term future, the next big project may be a high speed rail connection between London and the West Midlands. The government created HS2 Limited in January 2009 to develop the programme, and a recommended route was published in a report this past March. Following May's election, the new government has asked, HS2 to carry out further work on a Heathrow connection, to consider different ways of connecting the West Midlands, Manchester and Leeds and to plan a public consultation for early 2011.



Above: **Coring works start on the 6.4km Lee Tunnel for Thames Water**

Catch up on Crossrail

As contractors await the award of the two main tunnelling contracts for the GBP 15.9bn (USD 24.5bn) mega project, work on the stations is gathering pace. Bernadette Redfern gives this report

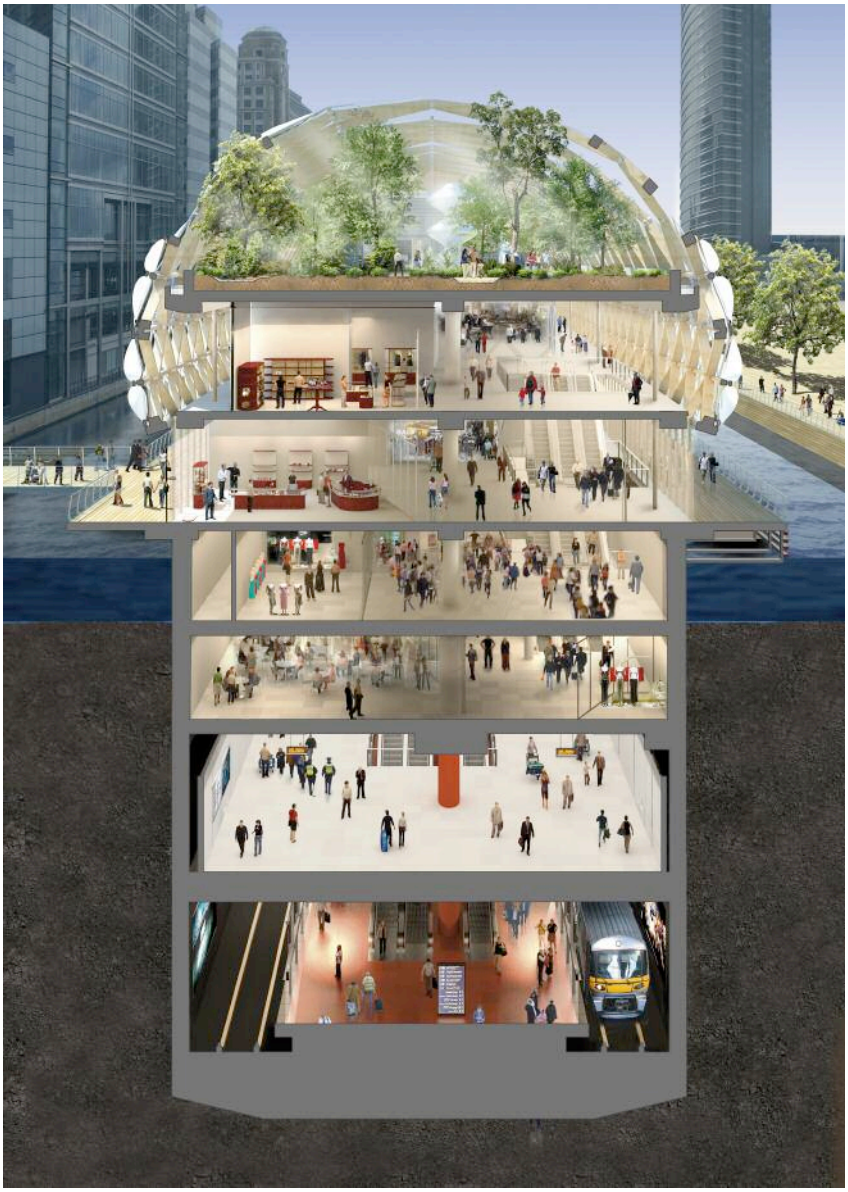
The UK's largest construction project is gaining momentum as more station upgrade work is awarded and contract appointments for 18km of twin bore tunnels are awaited. Five contractor consortia are in the running and expressions of interest have also been invited for a third tunnelling contract consisting of a 2.6km section crossing the River Thames.

A total of 42km of TBM bores are expected for the massive GBP 15.9bn (USD 24.5bn) railway, which will run east-west across London with 118km of new railway lines starting at Shenfield and Abbey Wood and running through central London to Maidenhead and Heathrow in the west. It will consist of four main lines: A 68km section from Maidenhead to Stepney Green Junction; a 30.5km line from Stepney Green Junction to Shenfield; a 13.0km length from Stepney Green Junction to Abbey Wood and a 7km spur from Heathrow Junction to Heathrow Airport (see map page 20).

Station upgrades

In terms of stations a total of 28 station upgrades are required for the Crossrail scheme mainly involving London Underground's major tube stations. Eleven of these are full reconstruction projects. A total of eight new stations will also be built for Crossrail including the first Crossrail station to get underway located at Canary Wharf.

Construction of the new 256m long, 30m wide station box began in May 2009 and set a tricky challenge for Canary Wharf Contractors (CWC), a subsidiary of developer Canary Wharf Group, which is investing GBP 150M (USD 232M) of the total GBP 500M (USD 772M) required for the scheme. The first activity for the GBP 500M project was to build a cofferdam to hold back the dock water and create construction space but due to the built up nature of the site, noise reduction was a key requirement. The team via sub-contractor Laing O'Rourke subsidiary Expanded Piling opted to use Japan's Giken piling method that claims to be silent thanks to the use of hydraulic pressure to drive the 18m long tubular steel piles. The rig crawls along the top of the previously installed piles and uses the reactive force of the ground to drive the next pile. A crawler crane sitting on a floating support barge then feeds the rig with the next steel tube.



Above: **The six storey station at Canary Wharf will contain four floors of retail space and is being developed by Canary Wharf Group**

A C-shaped clutch detail is used to hold the tube, which is then grouted up to form a water tight seal.

A second traditional piling rig follows the Giken to place the reinforced concrete piles. The first task is to pump out the water and then it excavates down to 33m. This

hole is then filled with the concrete and additional support is provided via anchor piles sitting just to the north, connected with steel cables. A total of 310 piles were driven and once the cofferdam was completed the team began dewatering the dock in February removing 98 million litres of water through two 6in diameter pipes. Construction of the six storey station box is now underway for completion in 2015.

The next station to get underway was Tottenham Court Road. A new station is required to service the Crossrail trains but the work underway concerns expansion of the existing tube station. Taylor Woodrow Construction and Bam Nuttall were announced as the winning contractor team in December 2009 and the scope of works includes construction of an enlarged ticket hall, new station entrances and additional access points to the Northern and Central line platforms to reduce congestion, along with additional escalators and five new lifts to provide step-free access. “The Tube station will be extensively redeveloped to make the ticket hall around six times larger and the station will have twice the capacity than at present,” says Miles Ashley, head of London Underground station capacity programme. "By 2017, Tottenham Court Road will be one of the most important transport hubs in the West End as it will serve both London Underground and Crossrail.”

The new Crossrail station to be built at Tottenham Court Road is yet to be tendered. However some extensive tunnelling work has already been completed at the station with contractor Birse having diverted over 40 utilities since July 2007. All works at this station will be completed by 2016.

The next stations to progress will be Paddington, Victoria, Bond Street and Farringdon. At Paddington five contractors have been invited to bid for the scheme including Bam Nuttall, Bovis Lend Lease, Carillion Capital Projects Ltd, Laing O'Rourke, Morgan Est and Vinci Construction Grand Projets. A GBP 700M (USD 1.08bn) contract for the redevelopment of Victoria station was also awarded to Taylor Woodrow with Bam Nuttall in March 2010.

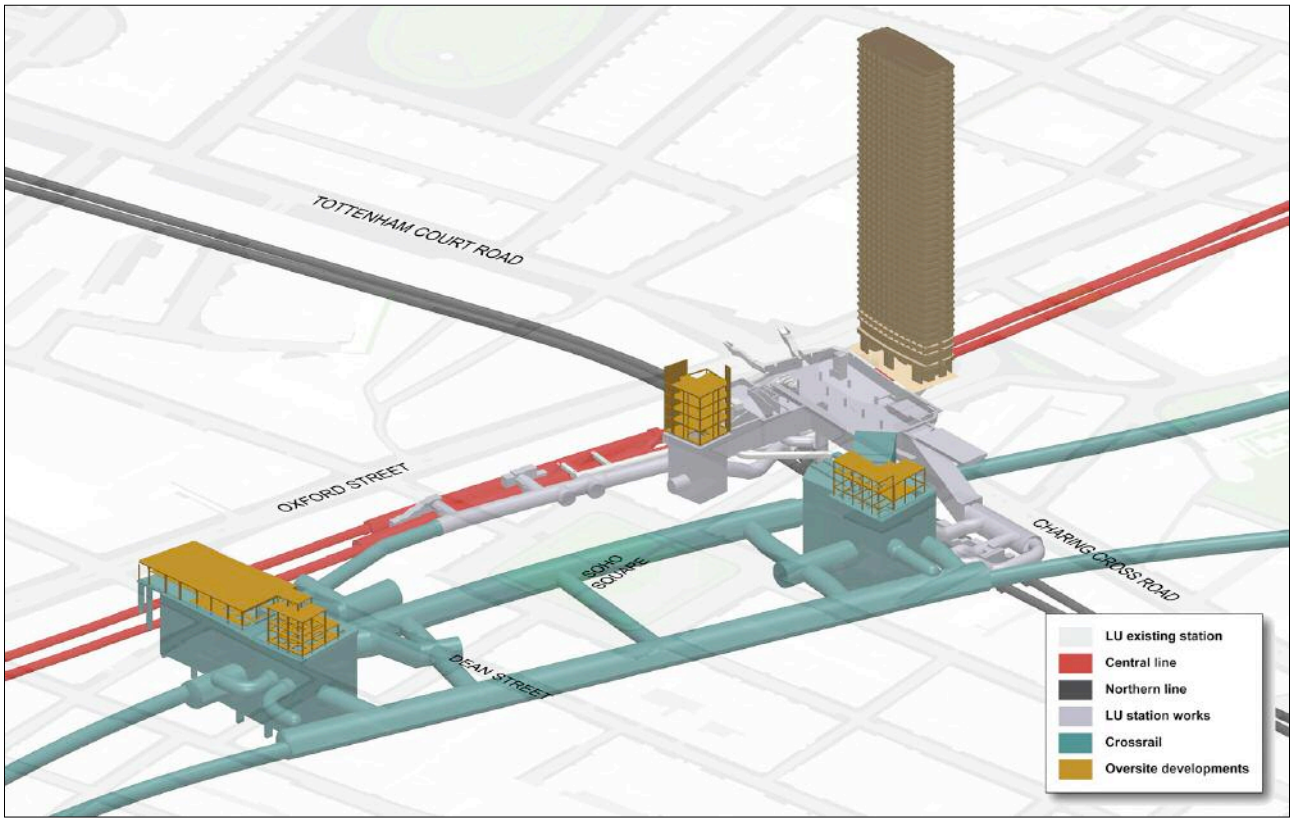
A GBP 300M (USD 463M) redevelopment of Bond Street Tube station was awarded to the Costain Laing O’Rourke joint venture last month. The contractor will increase the station’s capacity to enable it to serve over 225,000 passengers per day, from 155,000 today. Other requirements are a new ticket hall that provides step-free access to the Central and Jubilee Lines, new escalators and an alternative route to the Jubilee Line to ease congestion, as well as access to the new Crossrail station. "By 2017, Bond Street station will be served by both London Underground and Crossrail and will be a key gateway to the West End. This redevelopment is essential to ensure the station can accommodate the large increase in passengers that will use the station,” says Crossrail capital programme director David Waboso.

More station contracts for Whitechapel, Liverpool Street, Woolwich and Custom House are to follow.

Main tunnels

On the tunnelling side Crossrail will involve five main drives packaged into three contracts, the first of which is the Royal Oak to Farringdon section expected to commence in October 2011. Known as package 300 the western running tunnels contract involves the construction of twin 6.2m diameter bored tunnels from Royal Oak (west of Paddington Station) through to the new Crossrail Farringdon Station. The length of the drive is approximately

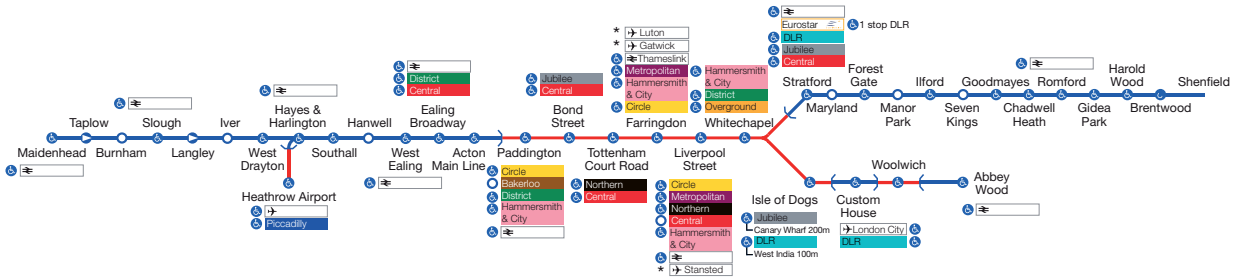
Below: **The first GBP 500M contract for development of Tottenham Court Road was awarded to Taylor Woodrow Construction with Bam Nuttall in December 2009**



Crossrail

Crossrail

Route Connections Map 2017



Key to symbols

- Step-free access from the platform to the street and for interchange platform to platform
- Station which requires the use of steps or escalators
- Surface line
- Tunnel
- Portal (tunnel entrance and exit)
- Connection with National Rail
- Connection with services to airport

The new line has a total of 42km of bored tunnes

6.2km including a crossover at Fisher Street. “The first of the tunnel boring machines will start out on its journey from Royal Oak towards Farringdon. This will be followed shortly by the launch of a further tunnel boring machine in Docklands that will head towards Farringdon under central London,” says Andy Mitchell, Crossrail programme director. This bore is expected to finish in March 2013.

The second contract is for package 305, the eastern running tunnels and this begins with the 8.3km bore of the 6.2m diameter tunnel from a portal at Limmo Peninsula through to the Crossrail station at Farringdon. The launch date is April 2012 and it is expected to take 24 months.

This contract also covers a 2.7km launch chamber at Stepney Green that runs through to the Pudding Mill Lane portal to begin in July 2013 and finish the following March. A further 0.9km launch chamber from Limmo Peninsular through to Victoria Dock portal is also part of this package and this is set to start in July 2014 for completion in December.

Five consortia have been shortlisted for these contracts and they include Balfour Beatty Civil Engineering with Morgan Est plc, Vinci Construction Grand Projets and Beton-und Monierbau Gesellschaft; a joint venture of Bam Nuttall, Ferrovial Agroman (UK) and Kier Construction (Team BFK); Costain with Skanska Construction UK and Bilfinger Berger Civil (Ingeneirbau); a joint venture of Spain’s Dragados and John Sisk & Son (Holdings); and finally a joint venture comprising Laing O'Rourke Construction and France’s Bouygues Travaux Publics.

Expressions of interest have also been invited for the third and final tunnelling package, contract 310, which involves construction of 6.2m diameter twin bores from Plumstead to North Woolwich. The 2.6km length will begin in September 2012 for completion in October 2014. Although this is a short section the work is expected to be challenging as the excavation will be conducted in Thames Chalk and it runs beneath the river. Contractors are expected to suggest the use of a slurry bore for this section. For the other four bores contractors are likely to use EPB machines for the works, which are mainly in London Clay. Compensation grouting is also expected to be a necessity thanks to the proximity and density of existing structures along the routes.

Mucking out

In total over 8 million m3 of spoil will be excavated to sites at Westbourne Park near Paddington and Limmo Peninsula near Canning Town. The Crossrail team is promoting re-use of the spoil and has a number of projects planned for the fill. At Wallasea Island on the Essex Coast the RSPB is submitting a planning application to Essex County Council for a project to raise the land, create hillocks and dips using Crossrail material. The new lanscape will allow the collection and flow of seawater and improve bird habitats.

Other material is to be removed via rail and water with excavated material being transported by barge from Instone Wharf on the River Lee, Isle of Dogs station, and Manor Wharf in the London Borough of Bexley. Rail movements will be taken from Royal Oak near Paddington. Material arising from the construction of stations and shafts will generally be removed by road transport. The final mode of transport will depend on the destination of the excavated material.

Despite its GBP 15.9bn price tag the UK government has remained committed to Crossrail with Mayor Boris Johnson giving it full support. However with a new government committed to cost cutting, the comprehensive spending review this autumn is expected to review all major expenditures. The Crossrail management team remains confident that it has priced the scheme as efficiently and appropriately as possible.

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One of the 2.44m diameter TBMs being lowered for launch

Brighton's sewer upgrade

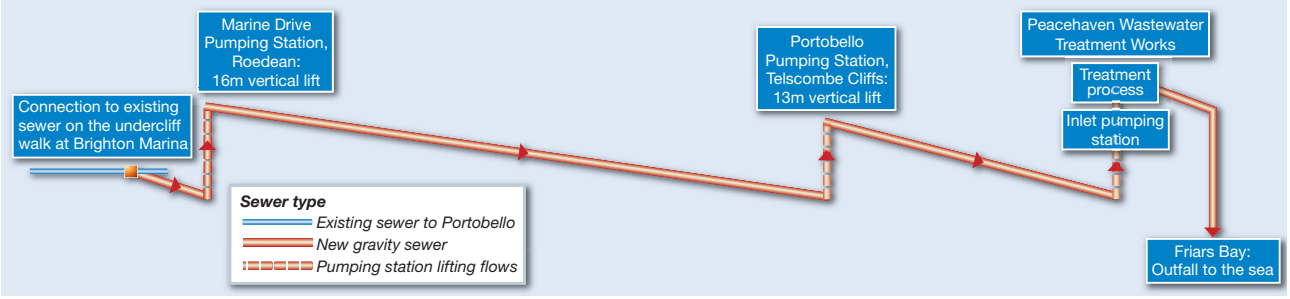
The largest tunnelling project currently underway in the UK got going earlier this year. Two TBMs will drive four tunnel lengths on top of two pipe-jacked sections. Kris Mole gives this report from site

Going back in history, back to the 1850s, Brighton was a little fishing village, no different to any of the other small fishing villages along the South Coast," explains Ben Green, senior project manager on Southern Water's Wastewater Treatment Scheme to bring cleaner seas to Sussex. "There was a doctor who lived in Brighton, Richard Russell, who wrote a dissertation on the beneficial effects of seawater. It quickly became a best seller and popularised Brighton as a seaside resort."

Green continues, "The problem was, at that time, most of the city wasn't served by a formal drainage network. There was some sort of surface water and sewerage management system, but that just took the wastewater out and discharged it on the beach, which wasn't ideal when people were bathing in the sea."

More than a century and a half later wastewater management is once again a major issue in the city of Brighton and Hove and surrounding villages and towns, hence Southern Water's GBP 300M (USD 467.2M) environmental improvement scheme, whose slogan proudly boasts, "We're bringing cleaner seas to Sussex." The main part of the scheme is the construction of a new wastewater treatment works and sludge recycling centre in the East Sussex seaside town of Peacehaven, about 10km

Below: **A schematic showing the rises and falls along the tunnel length**



east of Brighton, which will treat the 95 million litres of wastewater generated each day by the residents of Peacehaven, Telscombe, Saltdean, Rottingdean, Woodingdean, and the city of Brighton and Hove. In addition to the works, some 11km of tunnels are being constructed to transfer wastewater to the new treatment works, and then cleaned wastewater from the works to a new 2.5km long sea outfall pipe.

The new scheme has been a long time coming, as the city currently still relies on a system developed by one of the great Victorian engineers Sir John Hawkshaw, who was commissioned to the job in the 1860s after a long political debate between the sanitationists, who wanted taxes to be raised and a new system developed, and the anti-sanitationists, who just wanted to extend the various outfalls further out to sea.

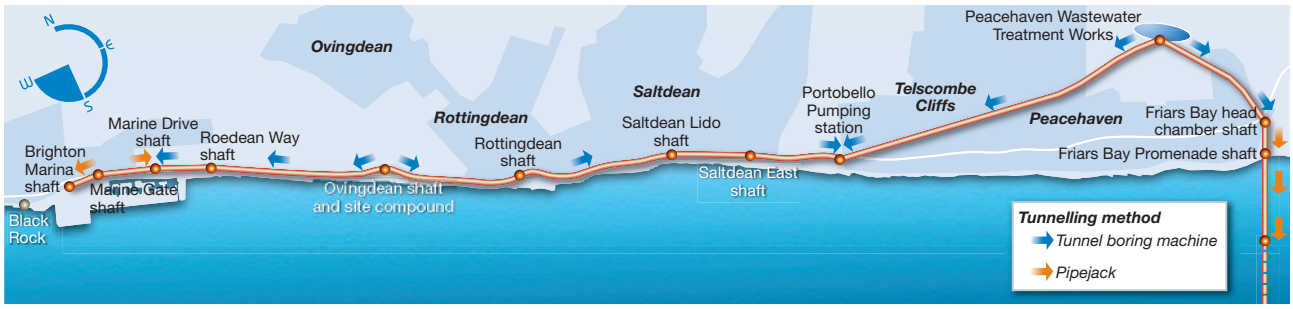
"The current system is a sewer pipe that runs along the coast down to the Portobello pumping station at Telscombe Cliffs [between Brighton and Peacehaven]. The flows receive only the basic treatment before being pumped out to sea through a 1.8km outfall pipe. The sewer pipe was dug by hand in chalk in the 1860s." explains Green.

The surge in investment in the water industry over the last two decades has been driven mainly by the establishment in the early 1990s of the Urban Wastewater Treatment Directive (UWWTD), which requires various standards of treatment in relation to population size. As part of the UWWTD, Brighton and Hove requires treatment of the wastewater to secondary standard. Another reason the city needs a new scheme is that the Victorian system was only designed for foul flows and not surface water or storm flows, meaning that right up until the 1990s all the storm overflows used to just go into the sea. This led Southern Water to construct Europe's largest wastewater storm tunnel, 6m in diameter and about 3 miles in length (4.8km), underneath Brighton beach, which serves as a storm water holding tank.

New sewerage works

Brighton and Hove's new sewerage system is being delivered by 4Delivery, a joint venture consisting of Costain, United Utilities and MWH. The 11km tunnel will start at Brighton Marina and follow the A259 coast road eastwards, first to the pumping station at Marine Drive, and then along to Portobello, where it will be pumped up once again. From Portobello the waste will be sent further eastwards down the remaining section of tunnel to the new treatment centre. A gradient of 0.2 per cent will convey the waste through the tunnels. Green explains the reason for using pumping stations is to ensure that the tunnel depth isn't excessively deep and remain for the most part above the water

Left: **The shafts will later house pumping stations**
Below: **The precast segments at the Brighton worksite**



Above: **A plan showing type and direction of tunnelling**
Right: **The sewerage processing facility at Peacehaven**
Bottom right: **A distant view of the treatment work**

table and sea level.

Two 2.44m diameter TBMs will create 9km of tunnels, with pipejacks driving a further 2km. Both TBMs have rippers with carbide facings to decrease the wear. "Costain expects these rippers to last through most of the drive lengths, without replacement, 1,600m. Flints are expected along most of the drive lengths but the rippers are expected to dislodge the flints out of the chalk matrix rather than break them up," says Southern Water spokeswoman Madeline Stoneman.

Each TBM, Alice and Hollyblue, are handling two drives. On the west side of the project the TBM is boring from the Ovingdean shaft westwards to the Marine Dive shaft. The machine will be taken out of the Marine Drive shaft, dismantled and returned to Ovingdean. Here it will bore eastwards to the Portobello Pumping Station shaft.

A huge barge, the Nordic Giant, has already dug the seabed trench into which the new outfall will be placed.

Costain's project manager (infrastructure) on the job, Craig Reade, explains, "we're looking to achieve between 10m and 40m a day in full production. The geology is essentially chalk, with some flint inclusions and possibly some seams, but nothing too challenging."

Advance rates at Ovingdean are approaching 40m per day (two 12 hour shifts) though it is hoped that this can increase to 60m per day. Excavation time for a 1m advance is around 10 minutes.

On the east side of the project the second TBM is boring from the Peacehaven Wastewater Treatment Works site to Portobello Pumping Station. It will then be taken back to Peacehaven and launched towards the Friars Bay Head shaft.

"The Peacehaven machine, Hollyblue, has a screw conveyor and harder chalk, has slower excavation times. Rates of progress are expected to increase as Hollyblue is not yet dully launched," explains Stoneman.

At each end of the project there is a section of pipe jacked tunnel. At the western end the works have been complicated by the proximity of the surrounding buildings and the stability of the cliff.

The Marine Drive Shaft is the meeting point for the TBM driven stretch from Ovingdean and the pipe jacked section from the Marine Gate Shaft.

"The site's almost 50m deep, 20m diameter shaft. It's also got a reception shaft to accept the 2.4m diameter TBM, which is currently on its way from the Ovingdean site and is about 300m in, due to come out in mid-October," says Green.

At the Marina site much of the cliff is chalk but some is wave deposited sands and gravel. Green says, "It's actually a raised beach. Apparently, in glacial times this was all just wave deposited sands and gravel up against the cliff, you can see the profile of the chalk, so we've had to take particular care here to make sure that the workforce is safe underneath that cliff. We had to monitor it every day as we worked to enlarge the chamber round the existing structure.

"We've actually amended the access route here. We've built an additional access route round the back of Asda because we didn't want to bring in all the construction machinery and the TBM through a busy car park with lots of pedestrians," says Green. "It's taken us ten years to get the planning permission, and to get the permission we've made a lot of commitments to a lot of people. Being a considerate constructor was a fundamental part of that. So when Asda said, 'we would prefer that the access is not through the site, can't you put an access route to the rear?' that's what we did."

The tunnels will be lined with a 2.44m i.d tapered trapezoidal ring consisting of six segments. These segments are cast using steel fibre concrete. Each ring is erected behind the TBM and grouted in place using a PFA/cement mix.

At each end of the works there are sections of pipejacked tunnel of 1.8m i.d. These pipes are formed of reinforced concrete.

Pumping stations

The first pumping station, situated at Marine Drive and with a 16m vertical lift, finds itself in a strange position. Green explains, "the only place we could get planning permission and all the land in order to build the pumping station was effectively through the middle of a traffic island in the middle of the road. But it's actually quite a strategic location."

He continues, "It's a place where the road opens up to two lanes going in to Brighton. So the council was keen to have a landmark gateway structure; they didn't want a standard pumping station. You've also got your million pound houses just above, and the residents didn't want their view spoiled, so the pumping station is actually set down into the road. There was an architects' competition to design the building over the top—the winning design has a zinc roof, Portland clad stone walls, and a stainless steel handrail. It's quite a weird shape, it's shaped like a fish or an eye, and it will hopefully be a landmark gateway feature to the city of Brighton that people will like and recognise."

The second pumping station at Portobello sits down underneath the cliffs of Telscombe, and has a 13m vertical lift. The existing flows from Peacehaven currently come down into the original chamber and then out to sea through the 1.8km outfall. When work is finished they will be re-routed around to the new pumping station being built next to the old one and then further eastwards to Peacehaven. On site, Green explains, "This is the existing operational site; it's where we take the screenings out. This was the site originally selected to extend. The works here would have been built on a platform out to sea, cutting back into the chalk a bit more, but due to the planning constraints it was not possible."

At the same time, Southern Water tried to get permission to build a wastewater treatment works at Portobello, but planning constraints meant that was turned down both at the planning commission stage and also on appeal. A public inquiry ruled out the works on the grounds that it was a Site of Special Scientific Interest, although historically the flow has always come through to that point.

Southern Water then still had this problem of where to build the treatment works, and that problem was actively worked on over the next decade.

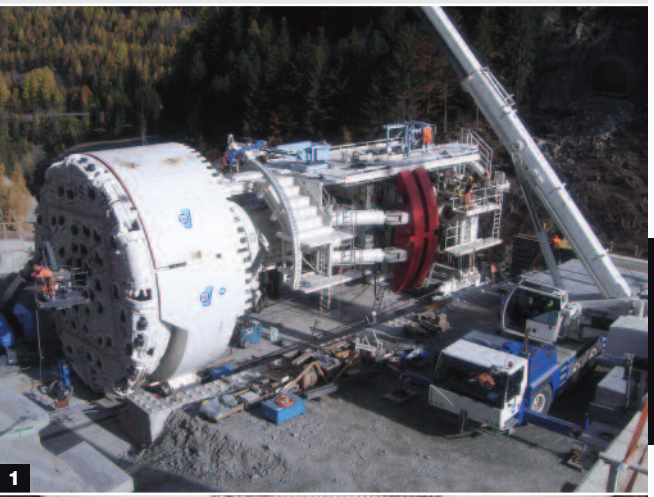
A shortlist of 66 sites was narrowed down to eight, and those sites underwent a strict assessment against construction, environmental need and planning. The site at Peacehaven, where the works is currently being constructed, was selected as the preferred option.

A planning application was submitted in 2005 to both Brighton and Hove City Council and East Sussex County Council because the scheme spans two administrative areas. Brighton and Hove City Council approved the plans, while East Sussex County Council didn't determine the application resulting in a public inquiry.

The secretary of state agreed that the revised site at Peacehaven was the most appropriate location but didn't like the look or the overall architectural design of the treatment works itself, so the scheme was re-landscaped and it also had a living green roof put on top of it to blend it in to the downland landscape. That went back to planning application and was passed. It then went back to the secretary of state to check that he was happy with it, and he was.

The objectors—and there have been many vocal and active campaigners against the scheme, due to the location being in Peacehaven—took it to judicial review in early 2009, but the judge said all the planning legislation was fine and that it should go ahead. So Southern Water eventually started construction of the current scheme in summer 2009.

Above: **A computer generated view of Peacehaven once work is completed**



1

2

3

4

1 TBM assembly at the main access tunnel portal, 1,100 m a.s.l.
2 Guide rails of the TBM trailers
3 Stacker conveyor mounted on tripper at the dump area
4 Gravel processing plant

TBM rebuild, conveyor belt systems, gravel processing plants: Marti Technics Ltd. offers multi-task expertise for your tunnel project

«Nant de Drance» pump storage power station

Builder and participating companies

The «Nant de Drance» pump storage power station, with a total capacity of 600 Megawatt, lies between the storage lakes of Emosson and Vieux-Emosson in the Valais mountains, and is a partner project involving Alpiq (formerly Atel), with a participation of 54 %, the Swiss Federal Railways (SBB) with a participation of 36 % and the Valais electricity company FMV, who has a participation in the project of 10 %.

Services provided by Marti Technics Ltd.

Inspection, conversion, delivery, installation and commissioning of the tunnel boring machine (TBM); design, planning and execution of the conveyor belt system, including the electrical installation and visualisation of the system control, as well as gravel processing plant, including an external silo facility.

Technical data

Tunnel boring machine S-522

Gripper – TBM	Ø 9.45 m
Overall length	145 m
Total weight	approx. 1,550 t
Installed power	5,500 kW
Drive performance of drill head	3,500 kW
Heading inclination	12 %

Conveyor belt system including electrical installation and visualisation of the system control

Length	5,540 m
Flow rate	1,000 t/h
Installed brake power	2,170 kW
Booster stations	3 units
Total quantity to be conveyed	1,050,000 t

The excavated material is transported in a downwards direction (600 m altitude difference), and the conveyor belt therefore requires a braking system. Energy is correspondingly fed into the power grid.

Gravel processing plant, including external silo system

Feed to gravel processing plant	150 t/h
Throughput of the crushers	140 t/h
Loading capacity	400 t/h
Water circulation	150 m^3/h
Storage capacity of gravel plant silo	2,500 t
Storage capacity of external silos	20,500 t
Installed power	2,700 kW

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20 years of steel fibre concrete lined tunnels in UK

John Greenhalgh of Bekaert looks at the increasing use of steel fibre concrete in UK tunnels over the past 20 years

Above, top: The DLR is one of many UK projects to use steel fibre concrete. Image courtesy of Morgan Sindall Above, bottom: Steel fibre concrete has been used in CTRL's running tunnels. Image courtesy of HS1

Some years ago a paper titled "10 years of steel fibre concrete a manufacturers view" (1) told the story of what had occurred in the UK market where fibres had actually been used in applications such as industrial flooring, external pavements and of course some tunnel works. Now, after almost 20 years, there much more to tell; a lot has happened regarding the use of fibres in the tunnelling industry not just in the UK but globally—more research, new guidance documents, the advent of the European standards for fibres and the relevant testing criteria, evolving performance based specifications, CE markings and of course, and more importantly, many more projects providing much more experience.

Main UK project experience

In the UK the first steel fibre segmentally lined tunnel was the 1.4km baggage tunnel at London Heathrow International Airport in 1995. This was a design and build project by Miller Tunnelling, now Morgan Sindall, in which the traditional reinforcement cage was completely removed and Dramix steel fibres used. By using the additional load bearing capacity that the high aspect ratio steel fibres give to the concrete, the lining thickness was reduced from the standard by 25 per cent, thus reducing the volume of concrete required and reducing the load being brought onto the lining

Further projects followed as the industry wanted to understand the concept, and a section of the Jubilee Line Extension was built using steel fibre concrete segments manufactured by Charcon Tunnels, now Tarmac Building Products. The 1.2km twin line ran from London Bridge Station to Southwark station. Costain Taylor Woodrow was able to report that the damage to the segments was surprisingly very low when inspected—also they made use of Dramix steel fibres for the first time in the sprayed concrete works but then all in the temporary linings (3).

One of the most prestigious projects to be undertaken in London was the refurbishment of the East London Line's Brunel Tunnel. The tunnel was originally completed in 1843 and had had very little done to it in terms of real maintenance over the years. By the early 1990s it was beginning to show its age and had some leakage that would only get worse in time. It was decided to refurbish both running tunnels entirely.

One of the main concerns was the potential of train derailing and impacting the new tunnel lining, so it was decided that a lining incorporating steel fibres with traditional reinforcement would be the appropriate solution. The lining would also benefit from resistance to potential thermal cracking and while maintaining a very small crack width, would provide excellent impact resistance; long term durability was considered and a corrosion resistant steel fibre was used in this case.

The fibre concrete was produced on site and pumped into the specially made shutters provided by Taylor Woodrow's production facility in West London.

Many projects followed in the 1990s, mainly in the utility sector, and into the new millennium with two major projects—the tunnelling works for the new Heathrow Terminal 5 (T5 HEX) and the Channel Tunnel Rail part 2 (CTRL). Both projects used steel fibre concrete throughout the majority of the works – both in sprayed concrete and the precast segmental lining for the running tunnels. It should be noted that these tunnels had larger diameters than most of the previous projects in London, >5m id for the T5 HEX Extension and 7.15m id of the CTRL running tunnels. However at T5 Morgan Sindall used a sprayed concrete lining method called Lasershell for the first time; the use of ribs and support arches were eliminated and a high strength concrete

Above, top and bottom: **CTRL has steel fibre concrete in both sprayed concrete and the precast segmental lining for the running tunnels. Images courtesy of HS1**

lining was sprayed containing high carbon Dramix steel fibres with a tensile strength of >2,400mpa that provided a high degree of ductility where normal low carbon fibres would not cope with these high concrete strengths.

For these projects a significant development took place that provided tunnel linings with the resistance to explosive spalling due to fire. After the first fire event in the Channel Tunnel a major test programme (4) was undertaken by Shuttleworth of RLE for the CTRL project. It clearly demonstrated the benefits of using micro polypropylene fibres-monofilament in concrete to minimise the explosive spalling and this work has since benefited tunnelling worldwide.

In this respect there have been some significant projects where steel fibres, usually with micro polypropylene fibres, have been used with and without traditional reinforcement cages and in some large diameter tunnels worldwide.

A major exercise was undertaken shortly after completion of the main CTRL tunnel works using Dramix RC-80/60-BN. It showed a remarkable lack of damage to the segments during manufacture, transportation and installation thus reducing repair time and costs significantly (5); these benefits are consistent throughout the tunnelling industry worldwide.

Based on this experience, the key requirements proposed for precast segments are mainly the following:

- Fibres should comply with the European Standard EN 14889-1
- Fibres with CE marking, system 1 (Fibres for structural use)
- Fibres of drawn wire, with a tensile strength of the steel wire ³ 1200 MPa
- Dimensional tolerances according to EN 14889-1
- Fibre length: 60 mm
- Aspect ratio l/d =80
- Glued fibres to ensure a good distribution and homogeneity in the concrete.
- Steel fibres must be added by way of an automatic dosing system
- Type of concrete: according to project requirement (C40 to C60)

In 2003 a design model from Rilem (6) was published for testing and design of steel fibre concrete. Today the existence of national and international recommendations on the sizing of the structures or structural elements made up of these materials are perfectly validated for steel fibre concretes.

Furthermore, clear test methods are now available for the designer to determined the minimum dosage for each project: Min. average residual flexural strength is measured with standard EN 14651 “Test method for metallic fibered concrete - Measuring the flexural tensile strength (limit of proportionality [LOP], residual).

FR, 1 is the residual flexural tensile strength corresponding with CMOD =0.5mm, which is the key requirement for SLS design

Conclusion

I do believe the UK industry has gained a huge amount of steel fibre concrete experience over the last 15 years or so in tunnelling. I think that if one adds up the total number of reinforced lined tunnels with steel fibre concrete in the UK the distance covered will exceed 100km.

I firmly believe this will easily be more than doubled in the next 10 years

Steel fibre concrete in tunnelling has been embraced in most countries around the world but it is only a matter of time before the use of steel fibres becomes almost the standard solution – not in all cases, but certainly in most.

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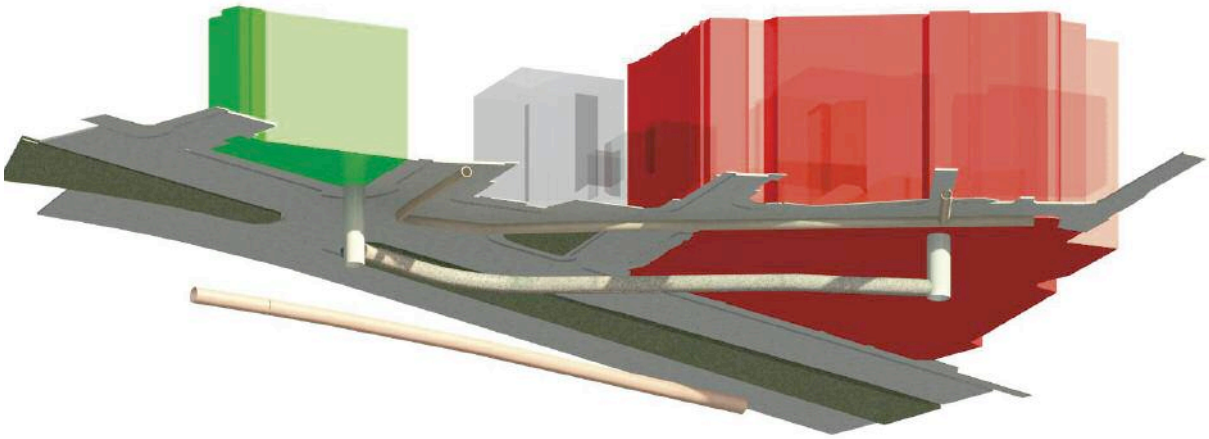
Digging under The Dorchester

Excavating a 2.7m diameter tunnel 12m under busy London streets and with only a hotel basement for access posed a challenge for designers and contractors on The Dorchester Hotel service link tunnel. Petr Salak of Mott MacDonald, Matt Mules of Kier Construction and John Comins of Joseph Gallagher give this report



As part of its expansion programme, The Dorchester Collection acquired a property at 45 Park Lane, close to its prestigious hotel in London, with the plan of refurbishing the existing building to provide a new annex comprising a penthouse suite, 45 exclusive rooms and a restaurant and bar. The 45 Park Lane building required substantial foundation work, refurbishment and internal fitout to achieve the required standard of construction, and the contract was awarded to Kier Wallis in August 2008.

In the planning stages, The Dorchester Collection chose to use the facilities at The Dorchester to provide the building at 45 Park Lane with hot and cold water, power and communications. Following an 'optioneering' exercise open cut works were ruled out due to the substantial disruptions it would cause to the hotel's operations and to the local road network. The decision was made to provide a service link between the two sites through a tunnel. A route passing under the hotel was considered but rejected because of the risk of damage to finishes. Instead a route along Deanery Street was adopted and discussions started with Thames Water, who maintain a sewer running above the planned line of the tunnel. Mott MacDonald provided a reference design for The Dorchester Service Link, prescribing 117m of 2.7m minimum i.d tunnel, and two 3.7m minimum i.d 12m deep shafts, with the contract being let as an ICE 2nd Edition Design and Construct form. The short length of the tunnel, the limited headroom at the shafts that would be excavated within basements, and the fact that the planned alignment was curved all lent to sprayed concrete lining (SCL) rather than segmental construction.

Part of the works would be completed within the basement of the 45 Park Lane building during the substantial main contract refurbishment works. While the main worksite would be located in the fully-operational hotel basement. In an effort to mitigate these interface risks, and to use the existing relationship that had been formed through the main contract works, project managers Buro 4, the employer's representative Mott MacDonald and The Dorchester Collection agreed to appoint Kier Wallis as the principal contractor.

Above: **Schematic view of The Dorchester Service Link showing the Thames Water sewer above the tunnel and the London Ring Main below**

In July 2009, following a competitive tender process, Joseph Gallagher, with Alan Auld Associates as its designer, was appointed as the specialist design and build sub-contractor to work "back-to-back" with Kier Wallis to deliver the project. The submitted construction methodology included innovative solutions to deal with the difficult work site locations.

Both shafts were constrained by the existing basement arrangements and by the limited headroom present—minimum 2.2m in 45 Park Lane building and 2.0m in the Dorchester Hotel.

Left: **The working area at the top of The Dorchester shaft**

Design development and evolution

The site's geological sequence comprised Made Ground overlaying Brickearth, with a layer of River Terrace Deposits leading into the London Clay—a typical geological sequence for the London Basin. Due to the presence of water bearing gravels directly beneath the basement floor it was decided that a form of ground treatment was required to reduce the permeability of the ground and increase the stability of the shaft excavation. A low viscosity, single shot Tam polyurethane grout was used. The grout reacted when it came into contact with water, to form a dense, solidified polyurethane foam.

The shaft internal diameters were dictated by the minimum space required for a safe method of construction. The depth of the shaft was derived from the requirement for one diameter of cover within the London Clay above the tunnel crown. This resulted in the shaft base level being 16m below ground level, which also provided a clearance of 6m to the invert of the Thames Water brick sewer in Deanery Street, which the tunnel alignment passed beneath.

The initial Mott MacDonald outline shaft design included precast concrete segments installed using underpinning methodology, with the lower section of the shaft formed using a primary and secondary SCL. During the detailed design stage Alan Auld Associates redesigned the shaft to be formed using steel liner plates. The SCL section was retained and designed to start 1m below the interface between the River Terrace Deposits and London Clay. The SCL was 150mm thick and reinforced with a single layer of A142 WWF. In the revised design the secondary SCL lining was replaced by a 200mm cast in-situ concrete reinforced with two layers of A252 WWF.

The primary lining in the 45 Park Lane Shaft was also revised to be formed entirely from steel segmental rings. No sprayed concrete work was prescribed in this shaft due to the difficulty of basement access during the extensive refurbishment works and to the severely limited space available for the necessary shotcrete equipment.

Following a detailed assessment of feasible tunnel construction methodologies, Joseph Gallagher opted for a primary SCL that allowed for mechanisation and settlement reduction. Mott MacDonald's primary tunnel lining design was refined to an unreinforced, 150mm thick SCL (C30/37) designed to carry the full ground load, surcharge and groundwater load in the short term. Immediate application of an initial sealing layer of 50mm was prescribed to minimise deterioration of the ground due to its exposure and to provide safety to the tunnel operatives. To minimise settlement, the excavation sequence was designed as a 1m round top heading followed by a 1m invert advance staggered 1m behind. After 55m of tunnel excavation and following a detailed review of observed settlement it was jointly decided that the full face could be advanced in 1m rounds to speed up the closure of the primary lining ring. This also simplified tunnelling and increased the advance rate.

The secondary lining was constructed using a cast in-situ, steel reinforced concrete lining, which was cast outside hand-built segmental steel formwork. While it would be acceptable to use SCL from a structural performance point of view and while technically the rough finish would be acceptable for a services tunnel, it was considered that the steel formed wet cast lining would help provide the high quality product the client desired. The secondary lining was designed as a 200mm thick cast insitu concrete (C32/40) with two layers of A252 mesh and was designed against full groundwater load, surcharge, ground load

Key challenges

- Very tight contract programme
- Logistical challenged of working within a basement structure with only 2.0m headroom
- Ensuring all approvals for the tunnel were in place prior to construction
- Respecting the operational needs of a luxury hotel, providing top level service to high profile guests for the duration of the project
- Slow early strength development of readymix shotcrete and inconsistent quality with respect to retardation and slump
- Ventilation in the basement and tunnel during spraying operations. More powerful fans and larger ducting were progressively introduced during the course of the project
- Curing time required for the sprayed waterproofing membrane caused logistical problems inside the small tunnel

Above: **The Dorchester shaft under construction using steel liner plates**

in the long term and to meet fire and durability requirements.

Mott MacDonald provided an outline design prescribing a 120 year design life of the tunnel and both shafts. This was achieved by assigning an appropriately durable concrete mix design with a 40mm minimum cover to the reinforcing steel. All structural steelwork has a 40 year design life; so galvanised steel was used for the access ladders and landings.

Excavation and primary lining

The precast concrete segments originally proposed for the primary lining of the shafts were substituted by steel liner plates supplied by American Commercial. Each 406mm deep ring was comprised of 13 no. 8mm thick steel segments that proved to be versatile, small, light and easy to handle during shaft sinking. The headroom in the basement was not sufficient to use standard hydraulic jacks nor manoeuvre heavy kentledge to sink the shaft as a caisson; so conventional underpinning was chosen. Prior to commencement, the River Terrace Gravels underlying the basement slabs were consolidated by injection of polyurethane grouts via lances driven into the ground. Although it was later found that penetration of the polyurethane resin into the dense sandy gravels was limited, both shafts were carefully and successfully sunk in single ring increments using a degree of timber support where necessary to minimise overbreak.

The bottom half of The Dorchester shaft within the London Clay was lined with 150mm of fibreless shotcrete, reinforced with a single layer of A142 WWF. The SCL allowed the integration of the tunnel eye with the lining, avoiding the need to breakout through the steel rings, potentially restricting access further by the requirement for temporary propping in the shaft. Both shafts were sunk during a 12 hour dayshift at an average rate of 1m per day.

Excavation of the 117m long 3.1m i.d. tunnel from The Dorchester shaft began on 14 January 2010 and reached the shaft at 45 Park Lane on 5 March, with tunnelling production ranging between 2-5m advance per day for fives days per week. Initially an 8T Butor electric-hydraulic excavator was trialled but proved to be too large to manoeuvre while mucking in the small confines of the tunnel. Following removal of the Butor a conventional diesel-powered 1.5 T Taekuchi excavator was lowered into the shaft and almost immediately a marked increase followed in production.

As is common when tunnelling in such restricted work areas it was found that the maximum tunnelling advance rate was limited by the mucking and concrete delivery operations.

Excavated spoil was loaded at the tunnel face into a 1m3 capacity bottom-discharging skip on 18in (457mm) gauge rails which, when fully laden, were pushed manually down grade to the “Y” branch turnout at the pit’s bottom and hoisted to basement level by the 3.2T SWL runway beam hoist. Clearance below the hook to the landing area floor was tight at 1.4m, which meant that the skip had to be rolled out from under the beam before it could be lifted and emptied into the muckbay using a JCB 520 telehandler.

The capacity of the muck bay in the basement garage of The Dorchester was approximately 57T. During dayshift the spoil was carried up the spiral ramp by the telehandler to an 8yd3 (6.1m3) skip situated adjacent to the hotel kitchens at the rear of the building in Deanery Street, while tunnel excavation continued.

Readymix concrete for the SCL was delivered in loads of 4-5m3, which suited tunnelling production and the storage capacity of the KBM6 Muhlhauser remixer in the basement adjacent to the shaft. Each load was received at a small hoarded area on the pavement outside the hotel in Deanery Street and was discharged into the remixer via a small chute through a hole in one of the pavement lights adjacent to the rear Ballroom entrance.

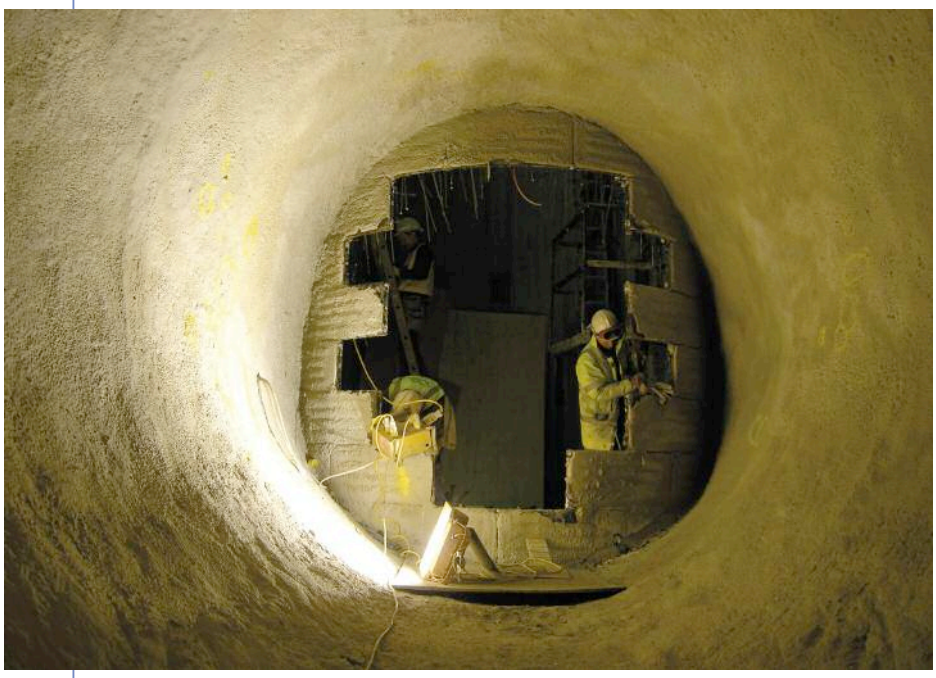
Above: **Excavation and mucking during tunnel excavation: 1.5T excavator and 1T hand-pushed skip on rails**

Waterproofing

The client’s requirement was for leak free, un-drained tunnel and shafts that will use the benefits of excavation in the low permeability London Clay and minimise the influence on the water table. Over the last 10 years, throughout the tunnelling industry there has been a shift away from sheet systems to the use of sprayed membranes for waterproofing. There are two types of sprayed waterproof membrane, reactive resin based systems and non resin based membranes, the later of which was used in The Dorchester tunnel.

The non-resin based system is an ethylene vinyl acetate powder based product, where water is added during the spraying process. Before the application of the BASF Masterseal 345 sprayed waterproofing membrane a regulating layer was used to ensure the receiving surface was not too rough, and hence reduce the consumption of the membrane material.

On average a 4-5mm thick layer was applied by hand-spraying with an application rate of approximately 50m2 per hour. In both shafts the cast in-situ secondary lining concrete contained a hydrophobic, pore-blocking Pudlo admixture to provide watertight concrete. Joints in the shaft lining, in the waterproofing system itself and between the tunnel and shaft linings were identified as weak points and therefore extra attention was required to seal them against water ingress. Tam re-injectable grout tubes were used in all construction joints.



Above: **Looking into the 45 Park Lane shaft following Masterseal application**

Testing and quality control

SCL testing consisted of the flow test, Hilti gun penetration test to check the early age strength development, cubes and cores to check the compressive strength. The sprayed waterproofing membrane was checked during the application with a simple depth gauge. After the application a full visual inspection took place and was recorded. Test patches were taken by peeling a 50mm x 50mm patch off of the membrane from the SCL surface, to check for the required minimum 3mm thickness.

Shaft and Tunnel Secondary Lining

Construction of the tunnel's secondary lining commenced on 12 March 2010 and completed on 30 April. The 2.7m i.d cast insitu tunnel secondary lining was formed behind hand built segmental steel formwork fabricated by Specialist Formwork. Each ring was tapered to suit the two 30m radius bends in the tunnel and comprised 10 segments. The weight of each segment was kept to a minimum to allow safe manual erection and dismantling and then striking after each pour. The tunnel lining concrete pours were generally 20m3 in volume and production regularly achieved the planned 8m of tunnel lining per day.

Settlement

The design necessitated the use of sprayed concrete for the primary lining to minimise face loss, settlement and potential damage to adjacent buildings along Deanery Street adjacent to The Dorchester.

Above: **The finished tunnel lining**

A series of monitoring points were installed on the road and pavement along Deanery Street prior to construction. These were measured by the contractor using precise levelling techniques at night when traffic was at a minimum.

Pre- and post- construction surveys of road and adjacent buildings have been undertaken by Plowman Craven and have continued on a monthly basis in order to confirm the cessation of any further tunnel induced settlement. During the project the volume loss was found to be a consistent 1 per cent and the change of excavation sequence was found to have no significant impact.

Role of communication

The ICE 2nd Edition Design and Construct form of contract prescribes certain roles both from the clients and contractors sides, however the organisational setup on The Dorchester Service Link included additional roles beyond those that are contractually required. The parties involved in the project were:

Client: The Dorchester Collection

Project Manager: Buro 4

Employer's Representative: Mott MacDonald

Principal Contractor: Kier Wallis

Specialist Sub-contractor: Joseph Gallagher

Contractors Designer: Alan Auld Associates

Other key parties involved in the decision making process included structural engineers for The Dorchester and 45 Park Lane building, and representatives from Westminster City Council and Thames Water. The large number of parties involved in the project necessitated an early and clear definition of the roles, responsibilities and the chain of communication.

A formalised communication and review procedure was established on site to ensure that any construction or design issues were identified and discussed at the earliest possible time. This system included Daily Review Meetings between the Joseph Gallagher, Kier Wallis and Mott MacDonald's Site Management, weekly meetings with the full site management team, non site based representatives and Alan Auld Associates and monthly meetings with the entire project team. These formalised measures were supported by regular open forums for all parties involved to discuss construction methodologies and the associated design requirements and issues that required resolution.

Through open discussion and a flexible approach to the design process, the site team was able to work together to pre-empt construction issues and develop the design in advance of these works to avoid delays. This collaborative approach taken by the site team was one of the major contributing factors in achieving a project completion on time and on budget, and highlighted the importance of forming good relationships between the client and contractor teams.

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CREATING TOMORROW'S SOLUTIONS

Stabilising ground conditions around tunnelling routes

Preparing the ground ahead of excavation can drastically cut the time and cost of tunnelling. Ian Clarke looks at some of the methods available to tunnellers

Anyone working within the tunnelling industry will know that it is somewhat of an expensive pastime, even more so when things go wrong. To prevent problems during tunnelling works, the planning of and correct establishment of a tunnelling site is as much a vital part of the tunnelling process as the actual tunnel construction itself.

As part of the tunnel planning process, ground investigation is essential. Not only does this tell the tunnel engineer what type of ground to expect to have to pass through—thereby dictating the tunnel excavation options available—it also gives the engineer the necessary information for any further forward-planning that may be necessary.

Where soft ground is present, high water table/pressure, fissured and or water-bearing or potentially unstable rock, the information provided by the ground investigation will indicate whether any form of ground pre-treatment is desired or necessary to prevent problems during the tunnelling phase.

Pre-treatment regimes can normally be classified into one of three broad types, dewatering, grouting or freezing. While this list may seem relatively simple, each subdivision has its own particular set of techniques and installation options as well as each having their own peculiarities to consider when it comes to their use. We shall look at an overview of the options available from each in turn.

Dewatering

While dewatering, or ground water control as it is sometimes referred to, may sound the simplest of the techniques being discussed there are aspects of this option that do bring various complexities with them.

Dewatering in essence is the temporary reduction of pore pressures or groundwater levels to provide dry, stable and safe soil conditions in or around excavations that lay below the natural groundwater level. The technique is generally used to facilitate construction of deep excavations such as those required for basements, tunnels and other underground structures.

Depending on the depth of the excavation there are three techniques available for the control of ground water levels deepwell, ejector and wellpoint.

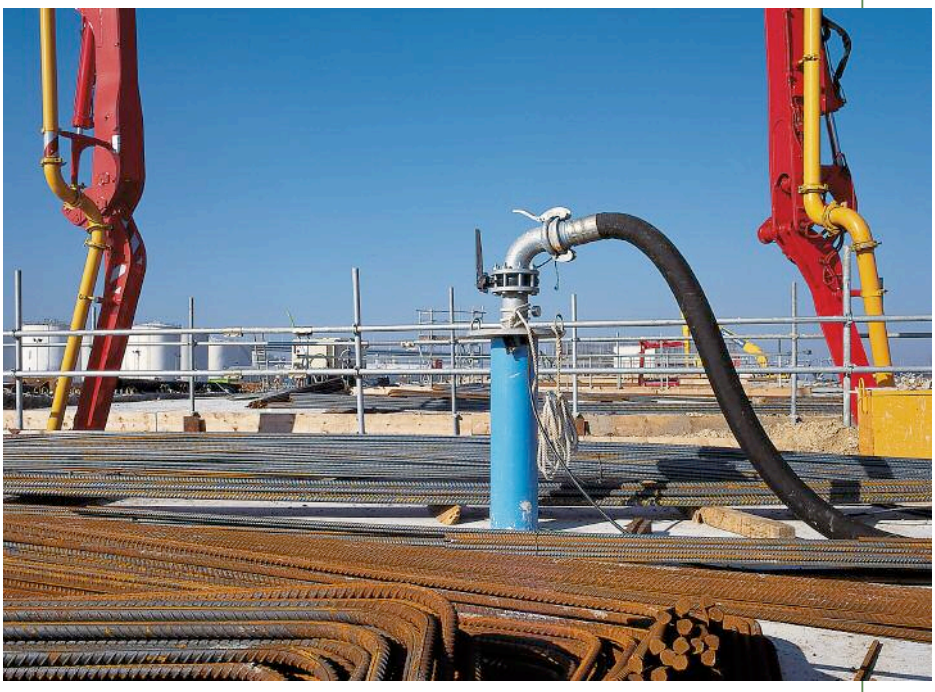
Deepwell dewatering systems generally comprise a series of bored wells designed to cover the area over which the dewatering activity is required to be effective. Each bore is fitted with a multi-stage electric submersible borehole pump.

In unstable and or granular soils wells are usually fitted with a liner and screen to provide borehole support while allowing ingress of the groundwater for extraction. Around the well liner the use of filter packs and grout seals may be required. Pumps are powered and operated from a central control cabin with the discharge water normally being collected via a ring main.

The deepwell technique is particularly suited to deeper excavations or where artesian groundwater pressures threaten ground stability during excavation and are best suited to homogeneous aquifers that extend well below the bottom of the excavation. The system is known to be a reliable one and the use of widely-spaced wells also helps to reduce access restrictions to a site to a minimum.

Deep wells can vary in diameter from 76mm to over 600mm and can be installed from as little as 6 m to hundreds of metres deep. Pumped volumes can also vary from just a few litres per minute to thousands of litres per minute.

Ejector dewatering systems (or eductor systems as they are sometimes referred to) are also used to control pore pressures and to lower groundwater levels to provide stable working conditions in excavations. Ejector systems are designed to extract groundwater and generate a high vacuum at the base of well bores at depths of up to 50m using bore diameters of as little as 50mm. The use of the vacuum drainage technique can dramatically improve the



Below: A deep well instalation by WJ Groundwater

Above: **A Unigrout unit injecting grout into the tunnel face**

Left: **A Keller grouting rig**

stability of silty fine sands and laminated silts and clays by controlling excess pore pressures within the ground structure. Ejectors are typically used where the groundwater must be lowered more than 4.5m and the soil is of low hydraulic conductivity so that vacuum application is of benefit to improve soil drainage. Since such systems are not limited in suction lift and generally have a lower unit cost than deep wells, ejectors are well suited for deep excavations in stratified soils where close spacing is required.

Supply pumps at ground level feed high-pressure water to the ejector nozzle and venturi, which is located at the base of each well. The flow of water through the nozzle generates the vacuum in the well and draws in groundwater from the surrounding soil, which is then extracted by the pumping system.

Wellpoint systems are more suited to the dewatering of shallower structures such as foundations and trench works.

A wellpoint system comprises a closely spaced series of small-diameter shallow bore wells that are connected to a common headermain. The system is driven by the use of a high-efficiency vacuum dewatering pump. For drawdowns in excess of 6m further stages of wellpoints are required, installed at successively lower levels as excavation proceeds.

Rapid and cost-effective wellpoint installation may be achieved in sandy soils by jetting using high-pressure water; drilling installation may be preferred in coarse or cohesive soils.

Sebastian Fisher, design manager of WJ Groundwater, says "groundwater control as a technique is designed to remove groundwater or reduce pore water pressure to allow stabilisation of an excavation/slope to allow construction in the dry. This means there needs to be a balance between a well-engineered scheme being put into place at the same time as making the technique cost effective so to be considered as an alternative to other stabilisation techniques. Groundwater control therefore adds another dimension to the geotechnical/civil engineering community with respect to ground stabilisation."

Grouting

Where grouting techniques can be used for the stabilisation of ground there are several techniques available to the engineer, some well-known and others not so well, but none the less available.

Grouting techniques as with other systems tend to rely on the use of boreholes into the unstable ground matrix that requires stabilisation. The grout is then pumped into the ground through the boreholes usually under pressure to force the grout mix through the borehole wall into the soil or rock matrix. Grouting can used to prevent water flow and to add structure to and unstable ground matrix.

The range of techniques available includes:

- Cement grouting
- Jet grouting
- Chemical grouting
- Compaction grouting
- Asphalt grouting
- Low-Mobility grouting

The conventional grouting technique is the use of Cementitious grouts as this option tends to be the least costly method. Cementitious grouts usually comprise suspensions of material such as cement/water or more stable cement/clay/water and admixture mixes. Other suspensions can include liquids, pure solutions (resins), colloidal solutions (gels) and emulsions.

Jet grouting is a construction process using a high kinetic energy jet of fluid to break up and loosen the ground, and mix it with a thin slurry. It is not really a true grouting technique but is rather a hydrodynamic mix-in-place technique producing a soil-cement material. The technique has three physical processes, which operate singly or in combination including:

- The very high speed jet loosens the soil
- The jetting fluid washes some of the soil to the surface
- The slurry adds a binder to the soil mix

A jet grout sequence normally comprises the boring of the grout hole followed by the introduction of the high-pressure grout fluid through a specially-designed nozzle on the end of the drill string at the bottom of the bore. The nozzle is then raised as the drill string is rotated causing the soil breakdown to occur. The fluid then mixes with the soils to settle back into the bore as the nozzle passes so creating the cementitious mix required for ground stabilisation. The fluids used can comprise various compositions including: single (cement only) fluid, double (cement with air) or triple (cement with air and water) combinations.

Chemical grouting uses a very low-viscosity chemical grout (polyurethane-based usually) that is pumped into granular soil to improve the strength and rigidity of

the soil to limit ground movement during construction. Chemical grouting is used extensively to aid soft ground tunnelling and to control groundwater intrusion. As a remedial tool, chemical grouting is effective in waterproofing leaking subterranean structures. A key advantage of chemical grouting is its ability to introduce grout into soil pores without any essential change in the original soil volume and structure, thus changing the support capability of granular soils without disturbing them.

From increasing the bearing capacity of soils under slabs and spread footings, to reducing liquefaction potential, arresting foundation settlement, lifting and levelling structures, providing pre-construction site improvement, and controlling settlement over tunnels or sinkholes, compaction grouting is a technique that can be used. Compaction grouting is a method of ground treatment that involves injecting a very stiff homogeneous grout mix, under relatively high-pressures, and at low injection rates into subsurface locations in pre-designed patterns in order to displace and compact soils. The injected grout pushes the soils to the side as it forms a grout column or bulb around the injection point.

Two other less commonly known grouting techniques also exist which are those of asphalt grouting and low-mobility grouting (LMG). Asphalt grouting has been used to plug leaks in cofferdams and in natural rock foundations. Asphalt is a brown-to-black bituminous substance belonging to a group of solid or semisolid hydrocarbons. When it is used for grouting, it is generally heated to 200° or 230°C before injection. Additionally, asphalt emulsions may also be used for grouting with these being applied cold. In the emulsion the asphalt is dispersed in colloidal form in water. After injection, the emulsion is broken so that the asphalt can coagulate to form an effective grout using special chemicals injected with the emulsion for this purpose.

LMG is used in situations where the grout mix needs to have a very limited ability to travel from its point of injection. These situations are common for grouting abandoned mines, karst solution cavities, and for water cutoff projects (similar to asphalt grouting for water cutoffs). The means and methods for LMG are very similar to compaction grouting, which by some is seen as a form of LMG with the exception that a slightly higher slump range is used on the grout mixes.

Many of the grouting processes covered above also now use computer-aided control systems to monitor and control the pumping systems that place the grout, helping to eliminate the potential for any human error in the grout mix, pumping pressure or placement.

Freezing

When it comes to freezing ground for the purpose of stabilisation and control, there are two main methods employed to create the supportive ice 'block'. These are known as mass and peripheral freezing. Both systems require the installation of a series of boreholes through the ground structures that are the cause of concern. The bore hole pattern must be of a range and distribution that the complete proposed excavation region in the ground is covered, probably with an oversized safety margin to allow for any unexpected occurrences.

The ethos behind freezing techniques is that once the bores are installed and the cooling tubes and refrigeration plant are in place, the circulating coolant lowers the ground temperature to the point where water and or moisture in the ground turns to ice. Continuing with the cooling creates a halo of ice around each individual bore. As this halo grows it overlaps with adjacent halos from nearby bores forming an ice block. Once all the halos interlink the ground is frozen solid.

The first technique, mass freezing, is the probably the simplest. This technique is used in certain circumstances where it may be desirable to freeze massive volumes of soil to facilitate excavation within the frozen stabilized ground. These types of freezes are less common than peripheral freezes.

Mass freezing may be justified where:

- Ground control in difficult subsurface conditions is crucial to the success of a project.
- No geological cut-off is present within reasonable depth below subgrade at a given location, which means the use of ground freezing may necessitate a mass freeze to artificially create a bottom seal that local geology fails to provide.
- There is concern about the overall safety of the operation.

The problem with mass freezing of course is that ice is not a soft substance so to create any tunnel or other underground structure would entail mining through the now very hard ground.

This is where peripheral freezing comes into its own. The general intent of peripheral freezing is to minimise the amount of frozen ground to be excavated. The boreholes used in the design of a peripheral freeze are such that the halos between the bores form a frozen wall, of the appropriate thickness

Above: Ground freezing on San Diego South Bay Ocean Outfall project

and strength that is created, for the most part, outside of the excavation area which but extends some distance inside the future excavation surface so that any freshly exposed face remains stable. Peripheral freezes must be formed with sufficiently watertight bases to ensure that excessive groundwater leakage from outside the frozen region doesn't develop as an upward flow into the unfrozen ground inside the frozen barrier. In essence the bore for a peripheral freeze should terminate in an impermeable layer in the ground strata.

Since frozen ground can be created with any freeze pipe orientation, ground freezing can be a very effective stabilisation tool for tunnelling operations. Vertical freeze pipes can be installed to create a frozen arch through which tunnelling can proceed. The sides of the arch extend to an underlying impermeable cut-off horizon below the tunnel invert, while short pipes are used to freeze above the tunnel crown. Vertical pipe installation can also be used to create a full face tunnel freeze.

Other typical situations in which peripheral freezes are suitable include:

- Shafts
- Large circular, open excavations
- Small connections between structures.

While the descriptions given above relate to using the technologies from surface down to the tunnel horizon, most if not all could be used from within the tunnel if absolutely necessary. However, the interruption to the tunnel's advance, and the potentially huge cost of installing such systems underground would tend to make such a move prohibitive. While this may not always be the case, the general consensus is that if the ground ahead of the tunnel face is likely to need pre-treatment it is best to look at doing it ahead of the tunnel face from surface if not before tunnelling starts.

Old and new secure rail link

Within a programme of suburban rail link improvements around the nominal 'Capital of Europe', Brussels, the Schuman-Josaphat link between lines 161 and 26 is a small but vital part. Leading tunnelling contractor Denys has combined new and old support methods to ensure that the work is completed largely unseen and unheard. Maurice Jones reports.

The long-awaited Brussels suburban rail programme to improve travel around the city and regional express (RER) links to the rest of the country has been progressing since the Millennium and is planned for completion in 2016. As with many cities, Brussels is affected by increasing road congestion that demands a convenient alternative public transport system. As well as this improved service to the public the authorities are well aware that an efficient transport system is important for the standing of Brussels as capital of Europe and the home to most European Union (EU) offices; a purpose that the new Schuman-Josaphat link will particularly target as it will cut travel times from the major EU office complexes to the international airport.

Most rail improvements are at surface level but the Schuman-Josaphat link between the suburb of Watermael, regional route to Namur, the EU offices and Line 26 (Halle-Vilvoorde) to the airport, will be entirely underground as necessitated by existing surface structures and other environmental considerations.

Project summary

Clients: Infrabel (National rail infrastructure management), and Belisris (as Maitre d'Ouvrage - Organisation set up by federal government and Brussels capital regional to promote Brussels as capital of Belgium and Europe)

Design engineers (tunnelling): Joint venture of Grontmij and Maunsell (now part of AECOM) with SGI

Contractor Lot 2/2: Leophat Plasky joint venture of Denys, CEI-de Meyer, Galère, Wayss & Freytag, and Jan de Nul Group

Compensation grouting specialist subcontractor: National joint venture of Denys and Rodio

Remote-control pipejacking ('microtunnelling') shield machines: Specially adapted Herrenknecht AVN 1800T and Herrenknecht AVN 2000D from Denys fleet, plus open shield for transverse pipes

Concrete jacking pipes and shaft caissons: SOCEA (Denys group)

Subcontractor for wall slots and mucking out: Votquenne

Whole project value: EUR 210M

Contract period: Started July 2008 to complete in July 2012 (1300 calendar days)

Three chain links

The work is split into three sections:

- Lot 1 – major enlargement of the Shuman underground station complex serving the EU office complexes and Line 161;
- Lot 2/1 – conventional, mainly straight, cut-and-cover tunnelling along city streets linking both ends;
- Lot 2/2 – mined tunnel and junction to operational Line 26 largely in the Plasky Zone beneath an avenue, and residential and commercial buildings.

The THV Leophat joint venture including Denys as lead tunnelling contractor won the contract for Lot 2/2. The whole project of three lots is valued at around EUR 210M.

The overall purpose of Lot 2/2 work is to align the new connection, involving a tight route, with the Lot 2/1 tunnel, and to continue to align with the existing Line 26 from Delta to Meiser by constructing a new junction. Whereas most of the tunnelling length, both on Lot 2/1 and under Plaskylaan in Lot 2/2, is under a wooded boulevard, the junction and its approaches have had to be routed beneath an environmentally sensitive area. Of particular note is the Isle of Houses (Huizeneiland) a group of properties occupying a triangular plan under most of which the junction structure will be situated.

This Lot 2/2 work has considerable demands placed on it, not only to complete on time and within budget, but also to work with minimal environmental disturbance.

Geology & site

As an urban area with a long history of construction, the Schaarbeek area of Brussels is well known, but could still present some surprises. The ground overlying the planned excavation is mainly of lime-sand into which the foundations of most of the surface structures reach. Below this, on the planned horizon of special tunnel roof support, the ground is of very fine sand.

Most of the horizon that will be occupied by the new tunnel is also of fine sand, but coarser than above, and also containing some bands of sandstone. Denys microtunnelling manager, Dirk Derycke, explained that site investigation including drilling to identify any cavities that would disrupt tunnelling, especially the slurry-shield machine to be used. In the past there have been some excavations discovered due to building stone extraction.

Structure & sequence

'With a planned cover of only 3-4m," explained Derycke, "it was decided that trying to carry out a normal TBM drive was not safe enoughl. Therefore we adopted sequential excavation combining 'microtunnnelling' with traditional methods

Above: **Denys' head of microtunnelling, Dirk Derycke, in the project offices nearby**

and compensation grouting."

The final structure will be of reinforced concrete to widths determined by the train operating envelope on twin tracks including the four tracks required at the junction. Working areas are limited by surface space availability, and so while it may have been simpler in construction terms to cut-and-cover, the environmental consequences were unacceptable. The work therefore called for considerable imagination on both design and construction procedures. Eventually it was decided to allow underground construction access from shafts or pits at each end of the construction lot, and with a main intermediate working pit at Victor Hugo junction. All mucking out has to be carried out underground, away from the area.

In an unusual design the construction sequence combines innovative mechanised pipe jacking with conventional (for Belgium) slot wall excavation and reinforced concrete installation 'piled' into the sandy ground, followed by conventional excavation of the intervening space to form the rail tunnel.

Fortunately there is no significant groundwater at these levels so no sealing is required during construction.

So, following construction of the working pits, with extension excavation to underground working galleries, the construction sequence is:

1) Under structurally sensitive areas, mainly the Huizeneiland triangle, initial 'compensation' grouting was carried out to determine initial support levels, followed by monitoring and compensation grouting during pipe jacking (see below).

2) Driving of DN3000 steel pipes in both directions by mechanised pipe jacking. The alignment of each of the four drives is along the top corners of the final structure following curves to border the rail route.

3) Using the major steel pipes drives, with a temporary floor, as access routes, the wall slots are dug manually. Steel-wire-reinforced concrete slabs with screw-jack props provide temporary wall support. Following excavation of each slot, steel-cage reinforcement to design in inserted into the cavity and concrete poured to create the final wall structure.

4) At the same time as wall construction, the position of DN2100 transverse concrete pipes are burnt into the side of the larger pipes. Once access in clear a compact jacking rig will be used to install these pipes across the final structure as a pipe roof.

5) Following completion of the boundary structure (concrete filled pipe-roof and reinforced concrete piled walls), the intermediate ground can be removed by conventional excavators down, and the concrete floor and roof slab installed.

Galleries

It was not possible to open-cut the necessary working and access pits full width. This resulted in a particularly complex construction at the Victor Hugo drive pit where provision was required for major pipe jacking in four directions, but also for spoil disposal via the existing Line 26 tunnel, and construction of the main rail connection to that tunnel.

Features of the Victor Hugo pit include an elongated raised ceiling across both rail routes (new and old) to allow transfer of the jacking pipes to the jacking rig positions by overhead crane. The underground excavation extensions, all mined, are supported with reinforce concrete and square steel sets.

As another environmental protection precaution, all pits are lined with sheets of acoustic absorbent material to reduce emitted sound and vibrations.

Compensation grouting

Dirk Derycke explained, "An important aspect of the project's success has been to reassure residents that no harm will come to their properties. Key to this has been a comprehensively monitored programme of compensation grouting under properties, dating from 1890-1920, that could have been affected by any subsidence issues."

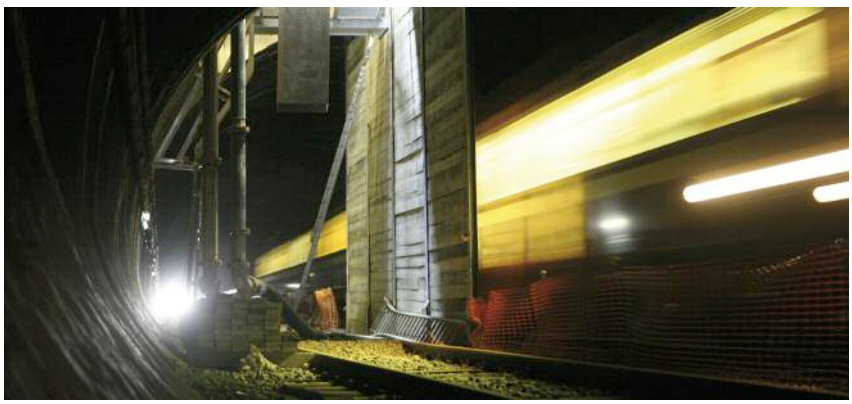
Monitoring of sensitive surface structures is carried out independently by surveying company Geomodus of Antwerp following an initial control survey. Reflector stations are installed on all buildings within the Huizeneiland by the tunnelling works. These are sighted automatically by two motorised Leica theodolites stationed at stable sites adjacent to the working areas, and using back sights, such as a nearby church, for reference. The system is sensitive to movements of a millimetre.

To monitor for any tilting each building in the survey area had a water level system installed in each basement, with 4-6 stations in each property. All monitored values are collected centrally in a measuring container on Plaskylaan and processed to produce trends and any necessary alarm values according to calculated differential settlements. Over 100 monitoring stations were installed, plus reference stations. The system has a precision of 0.01-0.03mm and is linked direct to the Denys-Rodio compensation grouitng system.

Prior to the pipe jacking the 'compensation area' of Huizeneiland was drilled under by three main fans of holes using compact Klemm drill-rigs mounted in two special 'injection pits' of 7m diameter sited outside the tunnelling zone. Each hole was fitted with *'tube-á-manchette'* packers to only inject grout in the exact zone to achieve the required effect.

Firstly the area was underpinned by

Below: **Below the Victor Hugo gallery one track on Line 26 contnues normal working while mucking out can take place on the other track from the chute (left)**



controlled cementitious grout injection to create a stable, level horizon upon which any subsequent adjustments could take place. This resulted in a structural lift of 4-10mm. As the main pipe jacking took place the resident Denys-Rodio grouting team employed the system to inject grout where any 'compensation' might be required for indicated subsidence or tilting. Grout pressures were 4-5bar.

However, as Derycke points out, the grouting difficulties do not end there. "The sand at the grouting levels already carries a lot of lime in the cavities, so grouting has to be carried out sensitively as we could not pump in a lot of grout."

Compensation grouting is expected to be required again when the second phase of pipe jacking, to install transverse concrete pipes, takes place.

Pipe jacking

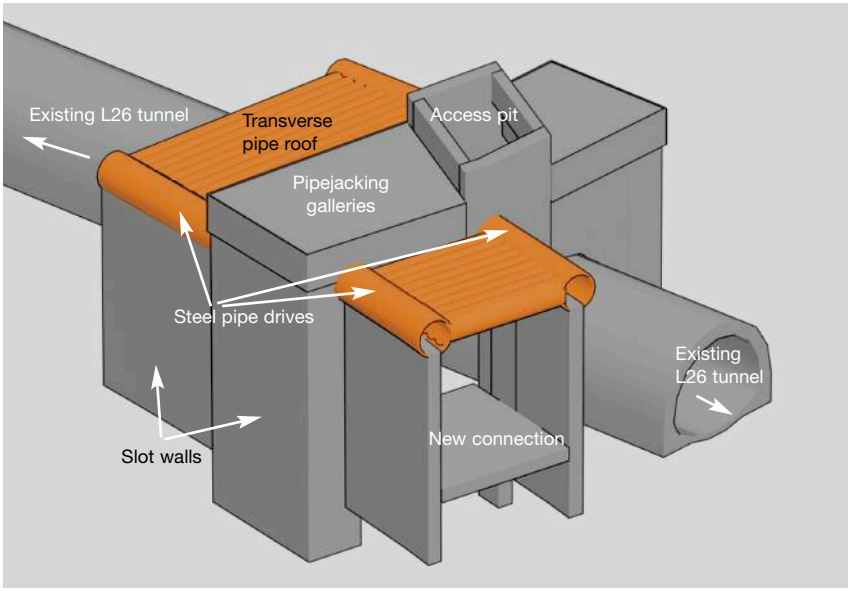
Denys employed its Herrenknecht AVN 1800T and AVN 2000D shield machines to install specially steel pipes along top corner peripheral drives as outlined previously. The pipes, 2.40m or 2.50m long to suit the tight 270m-radius curve required at the junction, were specially ordered from China. The shields were 'skinned up' to accommodate the larger diameter pipes and fitted with special cutterheads.

All the pipe jacking is being carried out from underground galleries, with the larger machines sited in the Victor Hugo gallery served with pipes by a specially installed overhead crane within the gallery. From here four curved drives were executed to the reception pits under Jamblinne de Meuxplein (to join with Lot 2/1 tunnelling 275m away under Plaskylaan) and Emile Max, on the alignment of Line 26 under the Huizeneiland. The AVN 1800T was used for the two longer drives, each of 275m, under Plaskylaan, whilst AVN 2000T was used for the two 100m-long drives under Huizeneiland and including the smaller radius curves. The planned route was maintained by a laser-guidance system with motorised theodolite.

The machine was also equipped with a special pre-drilling rig to investigate for any cavities up to 30m in front of the shield and to inject grout through the same holes.

During pipe jacking the slurry was pumped 1.5km underground through the existing rail tunnel to another site for solids removal and disposal. This complies with a ban on all spoil movements by road other than those for the original shaft excavations. All pipe jacking will excavate a total of 9410m^3 of material.

No reception pit could be used on the Plaskylaaan drives as the necessary permits were not available. Therefore the shield machine was designed to be retracted through the installed steel pipes back to the Victor Hugo pit leaving the 'skin' and cutterhead behind.



Above: **Perspective of Victor Hugo working pit construction, pipe-jacking gallery, and connections to existing Line 26 tunnel and new Schuman-Josaphat rail link**

Another innovation was special seals to replace standard jacking gasket pads and to be more tolerant of the tight radius. Obtained from Jack Control of Switzerland, Dirk Derycke explained their operation. "They are rubber ring seals placed between each pipe as with normal gaskets. However, they are filled with water and, since water is incompressible, the jacking force can be transferred across an uneven or misaligned surface more than normal gaskets. The ones we used can handle jacking forces up to 750t and can transmit up to 90 per cent of the total force."

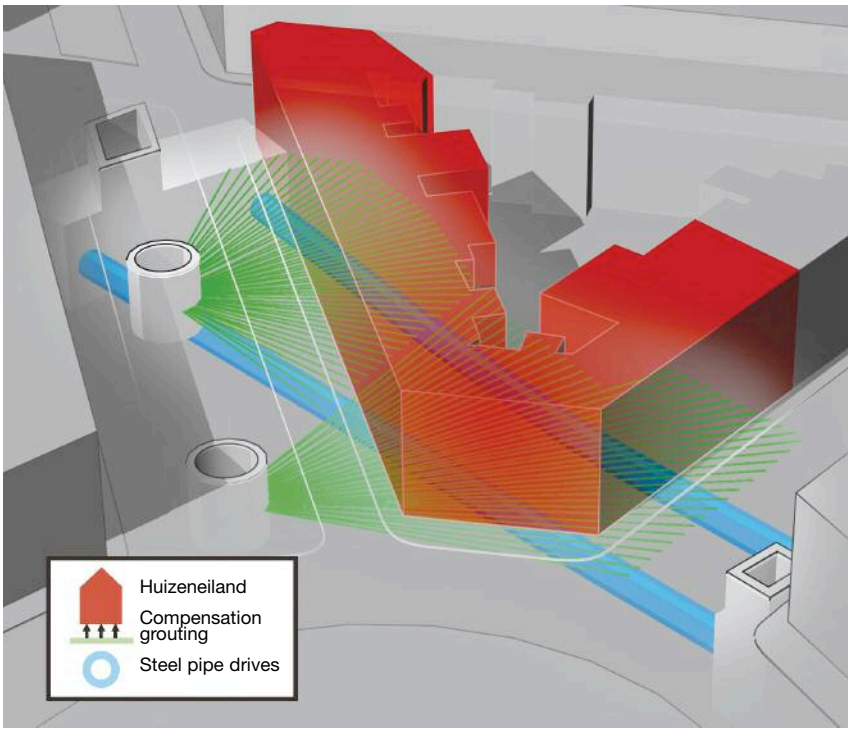
Actual jacking thrust was up to 650t, reduced by using an automatically controlled bentonite lubrication system, and up to three intermediate jacking stations. The total length of DN3000 steel pipe installed was 775m, and this part of the work is now complete.

Once the interior of the DN3000 drives are no longer required as access for wall slot construction, Denys will commence the driving of traverse pipe jacks using DN2100 reinforced concrete jacking pipes in November. The pipes are manufactured by SOCEA, a subsidiary of the Denys group.

Due to the limited space availability Denys has ordered the manufacture of a special compact pipe-jacking rig that can work within the larger pipes. The position of each pipe section has already been burnt into the steel pipe wall. A total length of 1200m of these pipes, each 800mm long, will be installed in drives approximately 10m long each, using an open-face shield. The spoil will then be washed out.

Above: **Busy excavating the wall slots**

In the final structure each pipe will be filled with reinforced concrete consuming 992t of reinforcement steel and 8368m^3 of concrete. In the zone from the Victor Hugo pit under the Huizeneiland until the alignment with Line 26 is reached, the roof was deemed to be too wide to be supported by the transverse jacked pipes alone so reinforced concrete roof beams, cantilevered 3.68m from the sidewalls, will also be installed here.



Above: Drilling compensation grout holes in one of the special shafts. Note multiple rows of holes. [Photo: Denys]; Right: Plan of the compensation grouting drill-hole fans from two special shafts to under the Huizeneiland

Once the transverse jacked pipes are installed the narrow space between each will be injected with grout to create continuous support. Once exposed in the main excavation roof the pipes will also be covered with a sprayed concrete lining to complete the main structure.

Wall slots

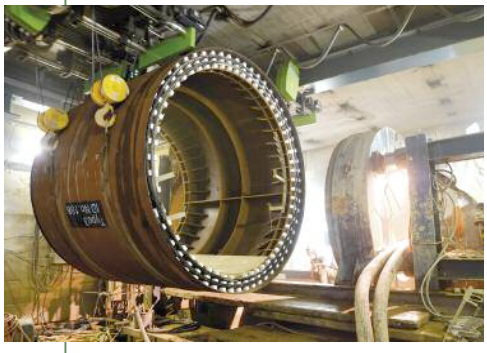
Following completion of the longitudinal steel pipe-jack drives, and the burning out of access lots, reinforced concrete wall construction could begin, and is currently in progress. Following traditional practice, described by Derycke as 'only in Belgium', the sand is dug out manually and hoisted from the slot by bucket. Each slot, to eventually join with its neighbour, is 3.05m long and excavated in 'lifts' of 400mm to match temporary concrete support panels. The width of the excavation is as required for the final wall design amounting to 1200mm in twin-track sections, and 1800mm in some zones, 20m deep from the top of the excavation.

Each temporary concrete panel is 50mm thick and 1.51m long with the central joint injection grouted.

The hoisted sand, and any harder material dug out by pneumatic tools, is placed in small rubber-tyre trucks and hauled through the DN3000 drive by a 3-wheeled battery tractor to the Victor Hugo working pit. It is then dumped through a chute to wagons on one track of the existing L26 rail route, whilst the other track operates as normal.

Once a section is excavated and supported with the temporary concrete panels the reinforcement cage for permanent support is inserted into the open slot, followed by concrete placement. Each wall slot is worked on alternately to maintain sufficient support of the excavation and to allow the final concrete to cure.

Below: Loading one of the special steel jpipes into the jacking frame. Note the special filled rubber gasket. [Photo: Denys] Right: Commencement of steel pipe jacking from within the Victor Hugo working galleries using Denys' Herrenknecht AVN shield machine [Photo: Denys]



Managing ground risk

Nigel Legge of Nigel Legge Associates and Iain Suttie of Berwin Leighton Paisner look at the role of project management and contracts in managing ground risk

Ground risk, inevitably, remains one of the most significant issues for tunnelling and underground construction projects. In extreme cases unmanaged ground risk may result in catastrophic failure and loss of life, yet experience shows even relatively minor project incidents can have a disproportionate impact on construction, safety, programme and costs. These events continue to occur despite considerable technical progress with the investigation, characterisation and mitigation of adverse ground conditions during construction, implying wider project issues play a role.

Project management and organisation influence the management of ground-related risks. The law approaches these risks and how they may be effectively allocated and managed under a tunnelling contract; though there is room for improvement. As with all major or complex projects, the project strategy should inform and be reflected in the contractual approach adopted if ground risks are to be efficiently and effectively managed. Mismatch between strategy and contract form, or failure to consider how risk is managed and allocated, frequently lead to project distress and construction disputes.

Project management

The incidence of major tunnel failures remains stubbornly high, particularly in the urban environment. The Nicoll Highway failure in 2004 had a number of similarities to the Heathrow collapse 10 years earlier; more recently major incidents have occurred in 2007 at Pinheiros during construction of the Sao Paulo metro and during extension of the Köln metro in 2009.

A significant factor in the Pinheiros collapse and the earlier incidents was found to be systemic failure of project organisation and management.

Project ground risk and the attendant cost and time impacts will, to varying degrees, be contractually owned by both the contractor and client body. All parties involved in the management of the project can influence how this significant issue is addressed and should play an active role in the continuous review, mitigation and management of this risk. Project culture, partnering arrangements and a genuine cooperative approach to risk management yield significant benefits.

Above: **The Nicoll Highway collapse in 2004**

In the first section of this article various ways in which ground risk may be dealt with practically and through effective project management and organisation are discussed.

Risk management

Following the Heathrow collapse, the UK Health and Safety Executive (HSE) concluded that a formal "risk based approach to design, construction and management" was required. The subsequent application of more rigorous risk management principles—including the use of the Construction, Design and Management Regulations—has had a significant and positive impact on the industry in the last 15 years.

Risk registers for tunnelling and underground construction projects are now routinely used and frequently they refer to adequate site investigation as a risk control measure for excavation stability. It is not common however to see rigorous risk management principles applied specifically to the issue of ground risk and how this can be best managed. As an inevitable project risk, the ground should be the subject of a separate risk assessment identifying the full range of potential hazards and recommending how these are either eliminated or mitigated.

The Association of British Insurers/British Tunnelling Society Joint Code of Practice for Risk Management of Tunnel Works is now a requirement of insurance cover for most major projects. It covers a wide range of issues throughout the project cycle, including specific measures to address ground risk. Importantly, the insurers regularly audit projects to ensure compliance with the code. The joint code is increasingly used as a wider project management tool to ensure industry best practice and standards are applied on projects.

Site investigation

As ground risk is a consequence of inadequate understanding—principally of the distribution and behaviour of natural materials, although obstructions may be a greater hazard—it is important to conduct a site investigation whose scope matches the complexity and risk profile of the project.

One of the most common issues concerning site investigation is that this important activity is not procured early enough in the project cycle, and that inadequate resources and budget are allocated to it. This frequently results in increased risk during the tender, design and construction phases of the project.

Good site investigation data are of limited value if not correctly interpreted. Properly interpreted site investigation data form the basis for good design and are vital for ground risk management during construction. Adequate time, budget and resources need to be allocated to this important task early enough in the project cycle to inform subsequent stages, either by the client or contractor in a design and build situation.

Geotechnical Baseline Reports (GBR), increasing applied outside the USA, are used for the contractual allocation of risk and a basis for determining the contractor's entitlement to additional time and money in relation to ground conditions. Although not a design document, being typically prepared by the engineer, GBRs assist with the understanding and interpretation of factual site investigation data.

It is important that the site investigation process should continue during the construction phase, typically involving ground probing and investigation that may be combined with ground treatment. This should be written into the contract, especially where ground conditions are complex and or the construction method warrants it.

Design

Ground risk can be mitigated by requiring fully-engineered designs for all stages of the excavation and construction cycle. This was an important conclusion of the HSE reports into the Heathrow collapse. Empirical or semi-empirical designs, although necessary in certain situations such as very deep tunnels, do not adequately manage ground risk and are not used in the UK.

Consequential ground risks may exist, particularly in urban areas where underground construction results in ground settlement that impacts sensitive third-party assets such as rail infrastructure or historic buildings. Other examples include tunnelling near to or through aquifer Source Protection Zones. The additional time and cost to the project of managing third party interfaces, gaining approvals, etc. can be very significant and should not be underestimated.

Construction methodology

The construction methodology, including the use of additional support measures where required for stability, should have the flexibility to deal with the full range of anticipated ground conditions.

Monitoring is an essential aspect of underground construction and ground risk management. Effectively used it verifies that the ground is behaving in accordance with the design assumptions. The wider project organisation needs to ensure that adequate resources exist to gather and interpret monitoring data, and that robust emergency procedures and contingency plans exist if pre-defined trigger levels are exceeded.

Ground treatment can be effectively used to eliminate ground risk at source, either applied systematically from the surface or as part of the excavation cycle combined with ground probing and investigation during construction. The relative costs and time impacts of these two options on construction logistics and programme need management assessment.

Contract mechanisms such as Early or Optimised Contractor Involvement bring constructor experience to the project before design is finalised. Although the main purpose is to explore project cost and time efficiencies the process can also bring to light risk issues through construction experience in similar ground conditions, the appropriateness of construction methodology, equipment, etc.

The general legal background

The general principle under English law is that the contractor, unless his contract stipulates otherwise, carries the risk of adverse ground conditions, regardless of whether they were foreseeable at the time of tender.

This rule applies even if information provided by the employer at tender stage and perhaps later incorporated into the contract—e.g. site investigations or drawings, plans and specifications—proves inaccurate. English law does not imply a warranty from the employer that such information is correct.

Generally, the law will find that the contractor has satisfied himself as to the feasibility of the works and undertaken to complete them according to the terms of the contract. It will be a breach of contract if he fails to do so. It follows that he must bear any additional costs necessitated by unforeseen ground conditions.

A contractor may be able to argue, on particular facts, that the employer has warranted that the ground conditions will be as specified in the tender documents. However, many employers will seek to exclude any such warranties.

A contractor may also be able to claim damages from an employer on the basis that the employer has misrepresented something (e.g. particular sub-surface conditions) on which the contractor has relied to his detriment. But, in most cases, it will be difficult or impossible for the contractor to justify an action for misrepresentation.

The approach of the English courts to the allocation of risk for ground conditions has been followed in a number of other jurisdictions including Canada and New Zealand.

Ground conditions in standard form contracts

Unsurprisingly, the common law rule is widely seen as simplistic and potentially unfair—particularly in relation to major or complex civil engineering projects, where typically the employer will have undertaken detailed ground investigations before inviting tenders. As a result, standard form contracts designed for use in the civil engineering sector frequently include provisions that attempt to promote a more balanced approach to the allocation of ground risk.

For example, the ICE 7th Edition provides that:

- The contractor is only required to take into account information on ground conditions obtained by the employer to the extent that it was made available to the contractor prior to tender submission
- The contractor is deemed to have inspected the site and "satisfied himself so far as is practicable and reasonable" prior to tendering as to all risks (including ground risks) that may affect his tender
- If "physical conditions," which includes ground conditions, though the term is of wider application, are encountered during the works that the engineer decides an experienced contractor could not reasonably have foreseen, the contractor is entitled to additional payment and an extension of time in relation to these conditions

The detailed application of the relevant ICE clauses (11 and 12) has given rise to debate

amongst lawyers. Undoubtedly, however, they represent a considerable readjustment of risk allocation in favour of contractors.

The International Federation of Consulting Engineers (other than the Silver Book for EPC/turnkey projects) and IChemE contract suites contain similar provisions to those found in the ICE 7th Edition.

The NEC3 Engineering and Construction Contract (ECC) adopts a similar approach. It provides (clause 60) that the contractor is entitled to a compensation event in relation to "physical conditions" that "an experienced contractor would have judged at the [date on which the contract came into existence] to have such a small chance of occurring that that it would have been unreasonable to have allowed for them."

For the purpose of the project manager's assessment of the compensation event, the contractor is assumed to have taken into account:

- Site information specified in the contract data
- Publicly available information referred to in the site information
- Information obtainable from a visual inspection of the site
- Other information which an experienced contractor could reasonably be expected to have or obtain

Whilst these standard forms each attempt to set out a more balanced approach to allocation of ground risk—which may lead, as NEC3 is intended to do, to more efficient contract pricing, with the contractor not being driven to include a risk premium in relation to risks which he is unable to quantify—each can be criticised for not being more sophisticated. Indeed, ECC's approach to ground conditions has been criticised by one distinguished tunnelling engineer (Sir Alan Muir Wood) as falling short of "good practice." The criticism applies equally to the other standard forms.

The key issue is, of course, that none of these forms requires risk allocation to be measured against a detailed technical baseline.

As a result, it may be said that they do not go far enough in promoting the rigorous analysis and allocation of ground risks. Instead, they require the engineer or project manager to make a largely subjective assessment of what the "experienced contractor" could reasonably have foreseen—an assessment that may have a critical impact on a project's budget, programme and deliverability, not to mention on the parties' behaviour.

Contract solutions

It is, perhaps, surprising that the standard forms have not gone further. Certainly, a number of important tunnelling industry papers have promoted a more sophisticated approach to the identification and handling of project risk, both at project inception and during the works themselves.

As long ago as 1979, CIRIA published Tunnelling—improved contract practices, which promoted the use of GBRs. More recently, the Joint Code similarly advocated the use of GBRs and followed the American Society of Civil Engineers' GBRs for underground construction (1997).

A GBR is a detailed statement of ground conditions that is typically produced by the employer and used for tendering and, if incorporated into the contract terms, contract management. It sets out, as objectively as possible, a description of geotechnical conditions that are anticipated or assumed will be encountered during the works. For example, it may specify assumptions as to the level of the water table, the incidence of fissures or the amount of flint in chalk.

A GBR allows each tendering contractor to price a uniform set of assumed or forecast ground risks, promoting a more ready comparison of tenders and, prior to commencing the works, a measured contractual allocation of ground condition risk. The employer will retain cost and time risk for conditions that are more adverse than those specified in the GBR; the contractor takes the risk in relation to conditions that are no more adverse.

When referenced in the ground risk clauses of the contract, the GBR will provide the engineer or project manager with the means—missing from the standard forms—for deciding in an objective manner whether or not the actual conditions encountered entitle the contractor to additional money and an extension of time. In theory, this should lead to a reduced likelihood of disputes between the parties in relation to ground conditions.

In recent years GBRs have become an increasingly common feature of tunnelling contracts in the UK and internationally. In part, this reflects practice in the US. It is also a development that is being promoted by a range of industry stakeholders, including insurers. GBRs are now increasingly being used on a number of major tunnelling contracts within the UK.

Other contractual mechanisms relevant to ground risk

There are two broad elements to ground risk management in tunnelling contracts. The first is the initial, contractually-binding allocation of cost and time risk in relation to unforeseen ground conditions. The second is the continuous management of ground risk throughout a project's life.

The latter is an aspect of project management in its broad sense and can be realised through tools such as risk registers and the establishment of a culture of co-operation and integrated teamworking. It is worth emphasising here that a risk register is a tool for managing risk; it is not a means by which risk itself is allocated. It may be said that the standard forms, generally speaking, do relatively little to promote the adoption of such ways of working.

The obvious exception is the ECC, which requires a risk register to be maintained and risk reduction meetings to be held and generally seeks to promote at its core proactive risk management. It is another matter how successful the ECC always is in practice. But the embedding of these techniques and ways of thinking into the contract obviously aligns with and serves to promote behaviours that drive successful project outcomes.

Conclusions

The management and efficient allocation of ground risk will be improved by an early and adequate assessment of ground conditions. The scope of site investigation commissioned should be appropriate to the nature, complexity and value of the project. Increasingly, such assessments are being included in tunnelling contracts as GBRs, which allow for the allocation of ground risks between the employer and contractor to be made objective.

This increased transparency of risk ownership translates into a simpler, less contentious resolution of contract claims arising out of unforeseeable ground conditions.

At present no standard form contract directly promotes the use of GBRs. Bespoke drafting is required in order to achieve this contractual position.

Effective ongoing ground risk management throughout the life of a project requires the adoption of project management tools including monitoring, the use of risk registers and early warning systems. Most standard form contracts do not promote the use of these tools, despite the fact that they are now very well established. Even where they are provided for in a tunnelling contract, the culture of the project must nevertheless be actively developed and sustained so as to ensure that the benefits such tools can deliver are realised.

Seaside rendezvous

Born in Glasgow but raised in the Middle East, Costain's Angus MacKenzie had considered working in the Middle East, especially since he had originally started working in the oil industry. "That would have been an option then but I don't think my heart was truly in the oil industry. I like the idea of challenges, building things, difficult things."

He studied at Cambourne School of Mines, where he earned a diploma in civil engineering before transferring to a degree in mining engineering. He joined Costain in 2003 and since then has worked on a range of UK-based tunnelling projects that use both drill and blast and TBM methods. His first role with the company was as a senior engineer on shaft sinking and microtunnelling in Bath—a drill and blast project—before becoming a project planner on the Saliway BFO job in the Welsh Valleys. From there he became a senior engineer on the Margate and Broadstairs waste water treatment scheme before being dispatched to West Ham where he worked on the waste water project there.

Since May this year he has been a tunnel agent on one of the four machine drives that are at Peacehaven as part of the Brighton and Hove tunnelling scheme (page 23). "Primarily my job is ensuring that the tunnelling machine is being used at optimum efficiency. To do that I oversee a number of people such as mechanical and electrical foremen, engineers, shift bosses," he explains. "All we're trying to do is make sure the TBM is working correctly, it's getting serviced correctly, everything is safe and we're building a quality product and ensuring client satisfaction and happiness."

Despite there being green fields at the back of Peacehaven, it's a very constricted site. "The tunnelling compound, the area available to us is more akin to an urban site," he says. "We're working to a tight programme," he explains. "But it is a nice environment, we're out in the country effectively. Even though we're surrounded by a big construction site we're surrounded by lots of landscapes and hills that ultimately you won't be able to see what we're building here unless you drive down the access road."

Angus and his team are very conscious of the effect they may potentially have on the local population. "We actively monitor everything we do in terms of noise, dust emissions and any other environmental aspects. We work closely with Sussex County Council to ensure that we don't step over the mark in any of the planning limits that we have."

The job has also presented Angus with something else to be aware of. "One of the curious things about this job is that there is actually a planning restriction on ground bore noise and vibration for the tunnel boring machine itself," he says. "This isn't something I've come across before. Normally there is a general nuisance value but here we appear to actually have to meet strict limits, which will prove to be a challenge in the future."

As it is for many people in the industry, moving around to work on different projects is a crucial part of the job, though much of Angus' work history is UK-based. "When I joined Costain I lived down in Somerset but it was rare to have large tunnelling jobs in that part of the country, a lot of them are based in the South East," he explains. "About two years ago we moved to Canterbury which is reasonably easy access to London.

"For this job, four of my colleagues and I are renting a house. We get paid a subsistence amount that allows us to live somewhere similar to home – it's not quite the same as going home at night but it's better than being in a hotel," he says, before adding, "the five of us do get on quite well, there's no bickering."

Where will he be in the future? "I don't know – whatever rears its head and there's a whole heap of stuff we're looking into. National Grid, Crossrail and something in North Somerset to do with a power station, and I have no doubt there will be all sorts of London Underground station refurb work."

Product marketplace

QUANTUM LEAP IN FAN ENGINEERING AS FLÄKT WOODS ACHIEVES CERTIFICATION ON ITS RANGE OF LARGE JM AXIAL FANS

Fläkt Woods has raised the bar for fan manufacturers worldwide, utilising turbo-machinery technology it has achieved landmark EN12101-3 certification for 400oC for 2 hours (F400) on its range of large axial fans up to 2.8 metres in diameter by successfully testing a fan 1MW 1500 rpm, 2.24 metres in diameter.

The test of the Fläkt Woods fan with steel blades and steel hub is a significant development in fan technology.

Tested at the TST facility in Spain, the 2-hour test at 400oC is in accordance with the requirements of EN12101-3. The test was witnessed by representatives of Cobra and 2IT Engingenieria, Spanish civil engineering companies.

The largest of the fans from the new range are used in tunnel and metro application, with the 400C requirement being driven by a need to operate in the event of increasingly large fires.

Increasingly, fire designers and engineers are raising the boundaries of fire standards, so fans have to operate at ever-higher temperatures. Previously fans were considered safe if certified for 300oC for 2 hours, but now the market is moving towards a need for 400oC for 2 hours.

This test on the most highly stressed example in the range, with the greatest power requirement allows for a complete range of fans to be certified up to 2.8 metre diameter. Presently, there is little actual requirement for a 1MW example, but Fläkt Woods recognise that the boundaries are ever increasing, so this is looking to the future in range terms. Generally the fan size in a tunnel or metro application is increasing. It is also believed that Fläkt Woods is now the only manufacturer to have successfully tested a 2.24 metre diameter fan, running at 1500 rpm, with a 1MW motor.

The increase in speed from 1000 rpm (6-Pole) to 1500 rpm (4-Pole) is significant as it allows additional pressure development. Additional pressure development enables the 2.24 metre diameter fan at 4-Pole speed to be used in applications were designers might previously have specified a two-stage fan. A single stage fan will always be lower cost than a two-stage fan at a specific duty point, and as such the 2.24 metre diameter 4-Pole fan can be a more competitive solution.

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- 2 DIESEL locomotives SCHÖMA, type CHL 200 G, track 900 mm, year of construction 2006
- 1 DIESEL locomotive SCHÖMA CFL 200, track 900 mm
- 2 DIESEL locomotives SCHÖMA/Hudson, 135 KW, track 750 mm
- 1 Rotations-dump, type ROWA, for 2 waggons
- 28 Rotation-muck-car, type Hudson, track 750 mm, 4.75 m3
- 1 Fan model KORFMANN, type AL 16/AL 17 FU
- 3 Fan model Zitron, type ZEL 1-18-160/4
- 2 Fan model Zitron, type ZEL 1-24-630/6
- 2 Fan model Zitron, type ZEL 1-14-75/7
- 8000m Tubes Ø 500 mm/20", 5.5-6 mm
- 2300m Tubes Ø 350mm / 14"
- 2 Conveyors, axle distance 11500 mm, width 800mm
- 1 Tunnel conveyor, length 4'000 mm, width 1'200 mm
- 5 Conveyors belt, length 500 m, width 650 mm
- 6 Air-cooling-systems WAT, Type DV 300, including Korfmann-fans

Contact: **SCHLATTER PETER AG**
CH- 5084 Rheinsulz
Tel: 0041 62 874 32 02 Fax: 0041 62 874 32 12
E-Mail: info@schlatter-peter-ag.ch

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Tunnel Design Engineer	Sussex	Ref: PN4149

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Underground Station Specialist	S.E. Asia	Ref: PN4209
Shotcrete Specialist	S.E. Asia	Ref: PN4210
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dates & events

5 - 10 SEPTEMBER 2010
IAEG Congress 2010, Auckland, New Zealand
Contact : PO Box 90-040, Auckland, New Zealand
Phone: +64 9 360 1240
Fax: +64 9 360 1242
E-mail: iaeg2010@tcc.co.nz
web: www.iaeg2010.com

12 - 16 SEPTEMBER 2011
6th International Symposium on Sprayed Concrete, Norway
Sixth International Symposium on the modern use of
wet-mix sprayed concrete for underground support will be held in Tromsø, in the north of Norway.
Contact: Siri Engen The Norwegian Society of Graduate Technical and Scientific Professionals - Tekna;
fax: +47 22 94 75 01

21 - 24 SEPTEMBER 2010
InnoTrans 2010, Berlin, Germany
Unternational Trade Fair for Transport Technology
Innovative Components - Vehicles - Systems
"The future of mobility"
web: www.iaeg2010.com

22 - 24 SEPTEMBER 2010
TBM Technology for Large Diameter Tunnels - Tunnelling short course, Colorado, USA
Information and registration on the conference website:
www.tunneling.com/topics/tunneling_course_outline_2009.htm
Organised by: Colorado School of Mines
1500 Illinois St.
Golden, CO 80401

23 - 27 SEPTEMBER 2010
ISRM Symposium and 6th Asian Rock Mechanics Symposium, New Delhi, India
Symposium secretariat:
Central Board of Irrigation & Power
Malcha Marg, Chanakyapuri
New Dehli 110 021, India
Contact person:
Mr. V. K. Kanjlia, Member Secretary, Indian National Group of ISRM
Phone: +91-11-2611 5984/2688 2866/2410 1591
Fax: +91-11-2611 6347
E-mail: uday@cbip.org; cbip@cbip.org
Web: www.arms2010.org
Download First Bulletin

28 SEPTEMBER 2010
Tunnels and Tunnelling Conference
T&T, in partnership with the British Tunnelling Society will be bringing you the most important conference event of the year. With a special focus on the current and future technical developments in tunnelling construction along with a global view of tunnelling activity, the T&T conference promises to fill you in on everything you need to know heading into 2011. The conference will be held at the ICE in London. Contact: email; conference@tunnelsonline.info; tel: +44 (0) 20 7936 6848

3 - 27 OCTOBER 2010
ISRM international Symposium 2010 and 6th Asian Rock Mechanics Symposium, New Delhi, India
Contact: Mr. V. K. Kanjlia, Member Secretary, Indian National Group of ISRM: tel: +91-11-2611 5984/2688 2866/2410 1591; fax: +91-11-2611 6347; email: uday@cbip.org/ cbip@cbip.org; web: www.arms2010.org

6 - 8 OCTOBER 2010
5th International Seminar on Deep and High Stress Mining, Santiago, Chile
Contact person:
Professor Michel Van Sint Jan
Email: deepmining2010@ing.puc.cl
Further information on the website of the seminar:
http://web.ing.puc.cl/~deepmining2010/

9 - 11 NOVEMBER 2010
Harkány 2010 - Tunnel Construction and Civil Engineering Conference
Design and construction experiences from the tunnels on the M6 motorway
Design and construction experiences of the National Radioactive Waste Repository at Bátaapáti
Foresight, the near and the distant future, the vision for tunnel construction and civil engineering
Tel: +36 26 319 368
E-mail: geovil@geovil.hu

23 – 26 NOVEMBER 2010
Bauma China 2010, Shanghai New International Expo Centre, Shanghai, China
The Bauma trade show is famous for it's German event once every three years and the China show is rapidly growing to meet its bigger brother. Contact: Messe Muenchen bauma, China Exhibition Management Messegelaende, 81823 Muenchen, Germany
Tel: (+49 89) 949-20251; Fax: (+49 89) 949-20259; Email: info@bauma-china.com

25 - 27 JANUARY 2011
Underground Construction Technology International Conference & Exhibition, Houston, Texas
Trade event for underground utility construction focused exclusively on installation and rehabilitation of the underground infrastructure.
Tel: +1-301-694-5243; Fax: 1-301-694-5124;
Web: www.uctonline.com; UCT P.O. Box 941669, Houston, TX 77094-8669

1 - 3 MARCH 2011
International conference and exhibition on tunnelling and trenchless technology, Selangor, Malaysia
The 2011 conference orgaised by the Tunnelling & Underground Space Technical Division (TUSTD) at The Institution of Engineers, Malaysia (IEM), will focus on tunnelling in South East Asia, future challenges and management of safety and risk. Tel: +(603) 7968-4001 / 4002; Fax: +(603) 7957-7678; Email: Tunnel2011@iem.org.my Website: www.iem.org.my

26 - 27 OCTOBER 2011
Underground Infrastructure of Urban Areas, Wroclaw, Poland
This conference will discuss topics related to building tunnels and underground infrastructure in cities, such as geotechnical tests and town planning issues. Tel: +48 71 320 29 14, Web: www.uiua2011.pwr.wroc.pl

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Editor, 'Tunnels & Tunnelling International', John Carpenter House, 7 Carmelite Street, London, EC4Y 0BS, United Kingdom.
Fax: +44 20 7936 6826
Email: editor@tunnelsonline.info
Web: www.tunnelsonline.info

BRITISH TUNNELLING SOCIETY

16 SEPTEMBER 2010: **Tunnelling in Seattle - Past, Present and Future**
How tunnels have been used in Seattle and why they are now starting to push the envelope in American tunnelling. The talk will look in detail at recent projects, particularly Brightwater, and at the planned 58ft diameter bore for the Alaskan Way viaduct replacement tunnel.
Brightwater is a $2 billion new wastewater treatment system, which includes 14 miles of soft-ground bored tunnel. Currently under construction, the tunnels are being bored using 2 EPB and 2 slurry TBMs, and are notable for their long drives and high mining pressures. ICE, 5.30pm for 6pm start.

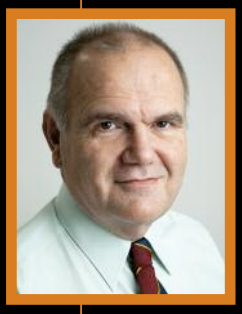
21 OCTOBER 2010: **Sir Alan Muir Wood Memorial Symposium**
The British Tunnelling Society is presenting a symposium on tunnelling and geotechnical themes with papers looking at recent tunnelling case histories, risk, and the inter-relationship of current design and research. Confirmed speakers include, prof Robert Mair, Prof John Burland, Prof David Muir Wood, Robert Muir Wood, prof Paul Jowitt and Martin Knights. Contact: bts@event-logistics.co.uk

18 NOVEMBER 2010: **Pittsburgh Northshore Connector**
Stephen Woodrow and Andy Miller of Faber Maunsell (AECOM) will deliver this talk on the light rail tunnels in mixed ground conditions with challenging vertical alignment.
The tunnelling works for the Northshore Connector Project in Pittsburgh, USA, involved several engineering challenges. The construction included 6.5m i.d. bore tunnels, 660m long passing under the Allegheny River. ICE, 5.30pm for 6pm start.

16 DECEMBER 2010: **Baggage tunnel design and construction at Heathrow Airport**
Andrew Stephenson of BAA, Enrique Blanco of Ferrovial and Athur Darby of Mott macDonald give details on the challenges of constructing the tunnel under one of the world's busiest airports. ICE, 5.30pm for 6pm start.

contacts

Jon Young



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