OCTOBER 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON EUROPE

Reports from the St Martin La Porte adit, in France, and the UK's Hindhead Tunnel

TRENCHLESS TECHNOLOGY

T&TI reviews asset management and trenchless rehabilitation techniques

35.08 E

NEW MILESTONE: BIG SUCCESS IN SHANGHAI.

The two largest tunnel boring machines in the world reached the breakthrough to their target shaft in Shanghai on May 28 and September 5, 2008, respectively. With their gigantic diameter of 15.43 meters, the two Herrenknecht Mixshield machines, the S-317 and the S-318, have excavated the 7,472 meters beneath the Yangtze River in only 20 months. They reached their target exactly to the centimeter 10 and 12 months ahead of schedule respectively – with tunnelling performances of up to 144 meters a week and dealing with a pressure of up to 6.5 bar. The two three-lane road tunnels with the subway line running beneath them connect the Changxing river island with Pudong (Shanghai) and they are scheduled to be open to traffic for the 2010 World Exhibition in Shanghai.

The "Shanghai Yangtze Under River Tunnel Project" sets worldwide innovative standards in mechanized tunnelling and is the new point of reference for large tunnel construction. Herrenknecht congratulates the Shanghai Changjiang Tunnel & Bridge Construction Development and the construction site team on this impressive success.

SHANGHAI I CHINA

PROJECT DATA	CONTRACTOR
S-317, S-318 **2x Mixshields** Diameter: 15,430mm Driving power: 3,500kW Tunnel length: 2x 7,472m Geology: sand, clay	Shanghai Changjiang Tunnel & Bridge Construction Development Co., Ltd.

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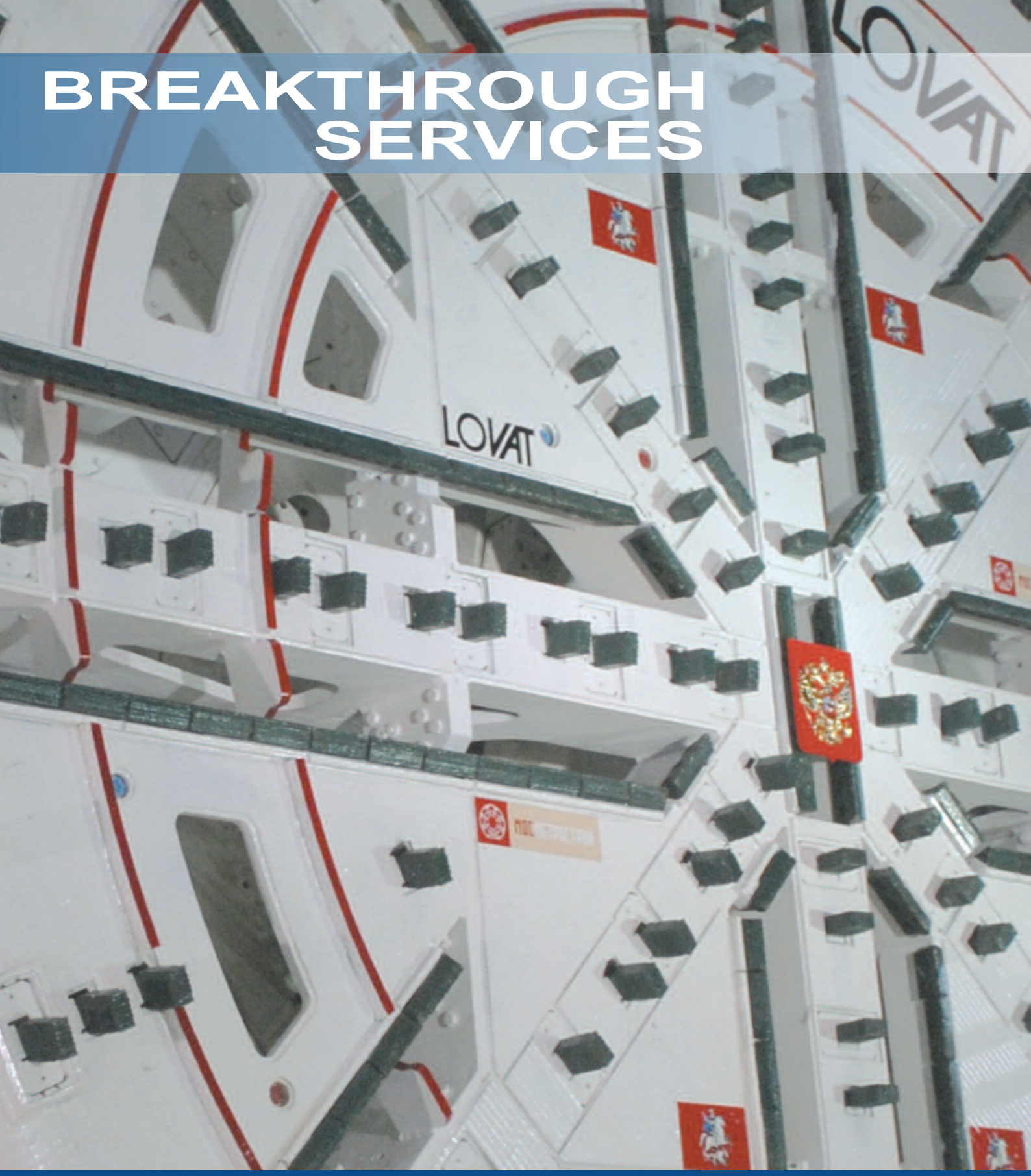

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It's not all bad...

If, as alluded to in last month's comment, Cern's large Hadron Collider doesn't finish us all off, then it appears that many of the world's more unscrupulous financial fat cats have been doing a pretty good job of it themselves. It's ironic, all that sensationalist media hype of mad scientists creating a black hole sucking us all to our fate, whilst a selection of insatiably greedy banks have surreptitiously created a gargantuan - and very real - black hole of their own, now sucking in hundreds of billions of dollars of tax payer's money in a last ditch bid to bail them, and hopefully us, out.

International news is dominated with grim tales of an impending, possibly unavoidable, world recession as economies crumble in the wake of irresponsible financial management. It makes for a depressing read, credit crunch this, credit crunch that, cascading house prices, widespread unemployment, even super power China has admitted to an unexpected fall in its economic growth rate for the third quarter in succession, with very real fears that its previously booming economy is heading for a severe downturn.

But hey, it's not all bad news. Far from a time to 'baton down the hatches', economic recession has historically proved to be a time for the civil engineer to thrive, as the shrewder governments re-allocate public funds and create initiatives for the development of much needed infrastructure. Roosevelt's heavy investment in the New Deal during America's rather oddly named 'Great' Depression of the 1930's can be sited as a clear example of nearly 10M jobs being created specifically to build infrastructure and provide a platform for the country's future economic growth.

It is a simple case of forward planning, and the benefits are two-fold. Much needed employment is provided during the bleaker days, whilst invaluable infrastructure is created to bolster the country's ability to compete on the international stage when the storm clouds of recession abate, as they always do.

So, instead of following the overwhelming trend of gloominess, cheer up, it could prove a time when civil engineers can stand up and really show their worth.

One word of warning though, with many of these large scale engineering projects being driven by public spending it is vital that the upper reaches of project management are placed in the hands of those best to deal with it. Many of the so-called professional 'money-men' have shown themselves incapable of managing money, a discipline they are supposed to understand, in a trustworthy and efficient manor. What hope of them managing construction, a discipline they most likely have little comprehension of, in any other way?

I genuinely hope this will never be forgotten, and that when these huge infrastructure projects get up and running it is Engineers at the helm, not bureaucratic financial meddlers who've had their chance - and blew it.

Tris Thomas

COMPANIES IN THIS ISSUE

Colombia's JV shortlist for La Linea tunnel

A shortlist of eight parties has been drawn up in the procurement of the trans-Andes "La Linea" road tunnel project in Colombia. The winning bidder is expected to be selected by the Ministry of Transport by the middle of next month.

The 8.6km long bore and associated new road links have a maximum budget of US$330M and construction period of 70 months, starting the end of this year. The eight competing parties for the contract are:

- a Korean JV of Posco Engineering & Construction and Daewoo Engineering & Construction;
- a Colombia-Italian JV of Impregilo, Conalvias, Tecnica Vial S en C, Infracon and Gevial;
- a Colombia-Chinese JV of Vergel y Castellanos, China Railway 18th Bureau Group, Oilquip, Jose Javier Castellanos Bautista and Alfonso Vergel Hernandez;
- a JV of Colombian and Brazilian firms comprising OAS, Mario Alberto Huertas Cotes, Procopal, Meyan and Ingenieria de Vias;
- a Colombian-Italian JV of Grandi Labori Fincosit, Translogistic and Contorn Contrucoes Ecomercio;
- a consortium of Colombian and Mexican firms comprising Condux, Constructora Herrena Fronpeca, Constructora Carlos Collins, Alvarez y Collins, Promotora Montecarlos Vías, Tuneles de Colombia, Construirte, Gayco, Tecnicíviles, HyH Arquitectura and Miguel Camilo Castillo Huertas;
- a Colombian-Chinese JV of APA and MSDI with China Gezhouba Group; and,
- a local JV of Conconcreto, CSS Constructores, Estyma Estudios y Manejos, Solarte Solarte Carlos Alberto and Solarte Solarte Luis Hector.

A full length pilot bore preceded the main project, which is being built as part of a bigger scheme to improve the transport links for road freight crossing the Andes between Bogota and the port of Buenaventura.

The section containing La Linea tunnel, at about 2,450m above sea level, is between Calarca and Cajamarca.

Hungary hot waste vault opens

Final checks of the tunnels and groundwater before Bataapati waste vault opens

A mining truck of the National Radioactive Waste Depository moves in the main tunnel of the Bataapati low and intermediate level waste depository in southern Hungary, in advance of its official opening this month. Checks of groundwater levels are important to the final preparations of the two access tunnels and the vault, which was excavated by drill and blast in fractured granite with low infiltration approximately 250m below ground level and lined with sprayed concrete, ribs and bolts. The depository will take drums of waste from the operation and decommissioning of the Paks power plant, pack them over with concrete and then backfill the drifts with a mixture of granite and bentonite.

Brisbane's Boggo Rd busway holes through

The ATM105 roadheader driving the Boggo Road tunnel in Brisbane holed through at the close of last month to complete the longest underground busway in Australia.

Work was underway on the 640m long drive since August 2007. The horseshoe-shaped tunnel has been excavated to a width of 14m and height of 7m (finished clearance is 6m), with a heading of 5.5m high followed by a 1.2m bench. The average mined cross section is 105m^2.

Variable geology along the alignment comprises both weathered and stronger tuff, and siltstones and sandstones. Support to the sequential excavation comprises shotcrete, lattice girders and bolts.

Much of the drive was under shallow cover – down to 6m below the sole building the tunnel passed under, which was a heritage structure.

The free surface, however, helped borehole sampling along the axis. The maximum cover was 15.5m, just slightly more than the span of the excavation.

With the geological model available at the pre-approval stage of the scheme, the contractor and consultant – Thiess and Sinclair Knight Merz, which were in the venture together with the Government of Queensland – were able to work in alliance to pick the best excavation and support options. The early close co-operation also enabled more effective job pricing.

The engineering outcomes of the closer co-operation included choosing lattice girders below the heritage building and otherwise employing plain shotcrete for the primary support.

Ground variability at the crown led to resin encapsulated bolts being picked over shell anchored or grouted bolts.

The 1.5km long busway, dominated by the tunnel, is scheduled to be operational by the middle of next year (*T&TI*, September, p23-26).

Chunnel sees Feb fix after fire

With spalled concrete debris from rings in the north running tube and most of the train having been only just removed, French rail accident investigators (BEA-TT) remain in possession of the fire-damaged stretch of the Channel Tunnel almost a month after the blaze - and told *T&TI* their probe has some time to go yet.

The owner and operator, Eurotunnel, has been unable to undertake a formal survey of the damaged section – "Interval 6" – due to the legal constraints of the BEA-TT investigating police and local courts. No verdict has been given for the cause of the fire.

However, the company has appointed Freyssinet to lead the civil works for the repairs, which will be supervised by SETEC. The track, catenary and other equipment will be repaired by ETF and Vinci, respectively.

Options for the lining and equipment have been drawn up. Eurotunnel said the works are to be completed by mid-February and the budget is Euro60M (US$81M).

The accident on a France-bound shuttle happened approximately 4km beyond the last crossover cavern and some 11km from the French portal, putting it in French territory. There were no casualties. Emergency services took passengers and crew out via a cross passage to the service tunnel.

Like in the last major blaze, in 1996 and also involving a freight shuttle with lorries in Interval 6, it is expected that, the accident of 11 September will also have resulted in sections of severe spalling of the concrete rings. No information has been given on the extent of the lining damage, but repairs took half a year after the 1996 fire.

The shuttle trains are approximately 800m long and most wagons were ablaze. It is estimated that fire damaged section may extend for approximately 700m, but Eurotunnel said there was no indication yet of the extent of such stretches. Neither was there information that colliery rings have been employed to ensure structural bracing, as done following the previous incident.

Soot and smoke particle pollutants had been blown down the north tunnel by emergency ventilation used to keep the air clear at the untouched front of the burning train. Following the limited resumption of services using only the south tunnel, Eurotunnel began cleaning work on the other, accessible stretches of the north tube – Interval 2, nearest UK, and Interval 4 between the crossover caverns. During the early recovery stages there was also provision made for a special train with medical isotopes to pass through carrying supplies for the UK.

A cleaning train was set to work with spray product on Intervals 2 & 4, and by late September both sections were back in operation.

Eurotunnel's Q3 revenues were down an estimated Euro22M (US$30M) due to the incident.

Cat finance, Lovat TBM for Edmonton

Edmonton's procurement of a Lovat TBM with financing through the manufacturer's new owner, Caterpillar, has paved the way for similar acquisition support for other potential customers, the company has said.

Caterpillar Financial Services has provided financing to the City of Edmonton to buy a 4.03m diameter shield to drive a 1,750m sewer tunnel. The TBM is to be delivered in the middle of next year, the latest of a number supplied over recent years for the sewer construction programme.

Financial details of the purchase and new funding arrangements were not available, but Lovat said: 'This facility is now available to all Lovat customers.'

The drive will be through weak clay shale and sandstone with cover varying between 30m-37m, and be below groundwater level. The four-spoke cutterhead will be fitted with rippers, scrapers and has a maximum torque of 3,000kNm at 1.9rpm.

The shield can be fitted with a screw conveyor for EPB mode excavation in future.

Shanghai giant bores done

The second 15.43m diameter TBM drives below the Yangtze river near Shanghai holed through early last month to complete major excavation of the twin tube transport link.

Herrenknecht's second Mixshield (S-318) started its drive from Pudong, near Shanghai, to the Changxing Island in the Yangtze at the turn of 2006. The TBM set off on its 7.17km long drive about three months after its sister shield, S-317, which holed through in late May.

Geology comprised sand, clay and rubble, and the drives reached a maximum depth of 65m below the river. JV contractor STEC/Bouygues achieved best progress rates of 26m in a day and 142m in a week, and the bores were finished about a year early. Lining is segmental rings (9+1), each 2m long. The tubes have cross passages every 800m.

The tubes will be fitted with double-decking, roads on top and the lower level will take service and safety installations, and maybe a metro link. The scheduled completion date is a year from now and they will be part of the new link between Shanghai and Chongming Island, the major island in the river.

The client is Shanghai Changjiang Tunnel & Bridge Construction Development and it supplied the TBMs. The shields – the world's largest – will stay in China though there is no immediate project assignment, said Herrenknecht. The tunnels were design by Shanghai Tunnel Engineering Design Institute (STEDI).

Kazan orders another NFM TBM

Above: Kazan metro orders second NFM shield like first

NFM Technologies has received an order for another EPBM to work on the expanding metro network in Kazan, in the Republic of Tatarstan, in the Russian Federation.

The 5.89m diameter foam-injection machine is to drive a single, 2km long tunnel for the twin tube section of the Central Line (Line 1) between Kozya Sloboda and Moskovskaya. The stations are to be opened in 2009 and 2011, respectively.

The EPBM is to be manufactured in NFM's le Creusot plant and is due for delivery to site in June next year. Geology along the alignment comprises sand and sandy clay. The client on the project is the city's metro developer, Kazmetrostroy.

Following the completion of the work the TBM – which was specifically designed also for ease of dismantling – is to be used for another project in Russia, said NFM, but details were not available.

This is the second EPBM that NFM has supplied to the project and it has the same characteristics as the first, delivered in 2004. The second was a refurbished NFM machine that had been used on the Copenhagen metro. It had its cutterhead diameter increased from 5.71m and was equipped to work in pressures up to about 3 Bar.

Site investigation for the metro first began in the mid-1980s during the Soviet era. Work proceeded to detailed studies in the late 1980s but the troubled finances of the Government led to a halt on all metro construction in the Soviet Union.

Construction of the Kazan metro did not start until 1997 and envisages a quarter century of development work. The first section of the planned, Central Line was brought into operation just over three years ago and presently has five stations, which running outward from the city centre are Kremlin, Tukaya Area, Sukonnaya Sloboda, Ametievo and Gorky.

NFM's first shield – "Altynchach" – was used for a 1.790m drive to build one of the tunnels between Kremlin and Tukaya Area, the other having been driven by a Lovat machine – "Syuyumbike" – the first TBM on the project, in 2000. The bore was the Lovat TBM's third of four drives.

Altynchach is currently excavating the second tube in the opposite direction, from Kremlin to Kozya Sloboda, the first having been completed earlier this year. The new NFM machine will be working on the next extension of the line beyond Kozya Sloboda.

Lovat supplied four EPBMs to Kazan's metro, the other being Katyusha, Olga and Polina. In addition, the metro scheme has bought three shields from local manufacturers.

Athens metro push

Major tunnelling on the Line 2 extension of Athens metro took a penultimate step to completion last month with breakthrough of the 9.46m diameter TBM at Ilioupoli station.

Following intermediate breakthroughs at Elliniko, Argyroupoli and Alimos stations, there only remains a short drive to tie-in the single tube, double-track extension to the existing line, the last station of which is Aghios Dimitrios. Excavation of the 5.5km long extension being developed by Attiko Metro began in February last year, and involves 4,655m of tunnel excavation.

The TBM is a refurbished and adapted Herrenknecht machine that has been erecting segmental (7+1) rings that are 350mm thick, 1.5m long and 9.18m o.d.

The shield is being operated by Seli, a member of the JV subcontractor for the tunnelling work. Other members of the JV are Aegek, Aktor and J&P-Aax. The main contractor is a JV of Aktor, Vinci and Siemens.

Line 2 extension was to have been completed in December 2009, but archaeological finds have led to this being put back by some months to early 2010. More than 80,000 passengers per day are expected to use the link.

At the opposite, north west end of Line 2, developments for further extension to the metro network include works to build links to Haidari, Peristeri and Anthoupoli.

The tender procedure for the link to Piraeus, which will have six stations, is underway. In addition, progress is being made on the design and procurement for Line 4, which will be 20km long and run in a major U-shaped loop in the north east of the city.

The line will have 20 stations and extend from the area of Galatsi to the centre of the city and back out to Maroussi.

Hope for Brighton sewer

Local authority backing for the stalled Brighton sewer on Englands south coast has given a boost to the possible resurrection of the scheme.

East Sussex County Council has given its support to the wastewater treatment scheme that would see approximately 11km of tunnel excavation and major shaft sinking.

The project developer, the utility Southern Water, hopes that the council's support for the latest proposals for the scheme will help bring the backing of the Government. Last year, government ministries refused permission for the project over concerns about environmental and aesthetic aspects of the treatment works.

There were no issues with the 2.4m i.d. segmentally-lined sewer tunnel but the design and build contract (IChemE 'Burgandy Book') could not go ahead. By then, the client had shortlisted two joint ventures – AMG (Black & Veatch plus Morgan Est and then Amec, before it joined with Morgan Est), and 4D (Costain, United Utilities and MWH). The plan for the tunnelling works is to have the sewer excavated in two drives, from Ovingdean and Peacehaven.

Brighton's new sewer scheme has suffered a number of development setbacks, and the proposal that was rejected last year was itself a re-submission made in 2006. The first effort to get the job underway was in 1998.

However, there have been some tunnelling works associated with the scheme. Last year, a precursor job involved Amec driving a very short drive to tap a live sewer at Blackrock (*T&TI*, September 2007, p10).

The project needs to be constructed to meet EU sewage treatment standards. The proposed treatment plant is to be sited at Peacehaven, and the scheme will also involve construction of three pumping stations and a long sea outfall.

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Barcelona gets ready for water bore pair


Seli will use a Mitsubishi-Robbins shield for the water bore in Barcelona


Herrenknecht is supplying a shield to the project

The first of two TBMs to drive the water transfer tunnel in the Fontsanta-Trinitat area of Barcelona was being prepared for tests in the launch tunnel last month while the second is en route to site.

Seli is undertaking a service contract to JV contractor FCC/Copisa to drive the 5.98m diameter Mitsubishi-Robbins double shield, which it is renting as well as the back-up equipment. It changed the cutterhead diameter and torque of the shield – now booked as DSU Seli 0598.119 – during a complete overhaul in its workshop.

The shield arrived on site in June and is being prepared in the launch tunnel to advance 200m to a ventilation shaft before, at this launch chamber with also a 100m long half-section tunnel, being set for the main, 5.6km long drive of the St Just tunnel. The first 200m advance is mainly under consolidation. While SCL lining supports the access and preparatory tunnels, the main bore will be lined with universal segmental concrete rings (5+1) plus inverts, and grout injection.

The job is Seli's first in Barcelona, and it noted that the JV has an option to buy the TBM and back-up equipment at the end of the excavation, which is scheduled to be completed in nine months. Geology along the alignment comprises mostly schist with some other metamorphic strata, such as grandiorite.

Herrenknecht is supplying the second TBM to another JV contractor – ACSA and Obrascon Huarte Lain S.A. – for the other, 6.2km long, Trinitat tunnel drive on the water transfer scheme to link the rivers Ter and Llobregat. Workshop acceptance of the double shield hard rock TBM (S-424) was in July.

The tunnels will be fitted with pipelines up to 2.4m diameter and the remainder of the bores will provide for security and maintenance access for vehicles. The tunnel will have three intermediate access adits with lengths of 820m, 810m and 33m, respectively.

The scheme is being developed by Aigues Ter Llobregat, part of the Catalunya regional government, to balance out water supplies between the catchments and has a total budget of US$270M. A pumping station will be built at Fontsanta.

Dibang bids called

Tender calls have been issued to build a battery of major tunnels for the Dibang multipurpose project in Arunchal Pradesh state in India.

The project, being developed by National Hydroelectric Power Corp (NHPC), calls for the construction of five 12m wide diversion tunnels totalling 6,260m in length, six 9m wide headrace tunnels with combined length of 2,700m and a similar scale of tailrace construction. An underground powerhouse will include three caverns.

Dibang's underground works are included in two bid packages: the diversion tunnels in Lot 3, which also includes construction of a dam and intakes structure; and, the powerhouse and both headrace and tailrace tunnels in Lot 4. Deadlines for bids for Lot 4 and Lot 3 are 31 October and 3 November, respectively. NHPC expects Lot 4 will take 78 months to complete and Lot 3 would last 90 months.

The five horseshoe-shaped diversion tunnels will have lengths varying from 1,175m to 1,325m. The six horseshoe-shaped headrace tunnels will vary in length from 300m to 600m and leading to 7.5m diameter circular pressure shafts of 184.8m length.

Of the three caverns, the powerhouse is the largest: 24.5m wide by 54.8m high by 382.8m long. The transformer cavern will be 19m wide by 31.5m high by 325.8m long. The smallest cavern is the MIV: 17m wide by 26.1m high by 277.8m long.

Back run for North Shore

The JV contractor building the North Shore Connector light rail link tunnels in Pittsburgh has turned and relaunched the 6.5m diameter TBM in the receiving pit to drive the second tube below the Allegheny river.

Obayashi and Trumbull, working as North Shore Constructors JV, early last month relaunched the Herrenknecht Mixshield (S-374) from the reception pit on the south side of the river. The shield was turned with a steel cradle and jacks in the pit, and the second bore is due to finish in late December.

The JV launched the slurry shield in January from the north side of the river and completed the 680m long drive in July. Combined with cut and cover stretches, each tunnel will be 1.9km long.

Geology comprises mainly silts, sands, gravel shales and claystone with lenses of limestone. While the drives are relatively short the hydrostatic head is up to 14.5m, and cover to the riverbed is 6.5m.

The US$156.5M contract for tunnels and other works was awarded in 2007 (*T&TI*, August, p7).

TBMs bite at Jinping II

Two 12.4m diameter TBMs – a Robbins main beam and a Herrenknecht hard rock gripper – were launched last month on parallel 16.7km long headrace drives at the Jinping II hydropower scheme in Sichuan province, China.

The project developer – Ertan Hydropower Development Co Ltd (EHDC) – has two of the project's four headrace tunnels being driven by TBM and the others by drill and blast.

Separate contractors are using the shields - China Railway 18th Bureau (Group) Co Ltd driving the Robbins TBM, and China Railway 13th Bureau (Group) Co Ltd the Herrenknecht machine (S-405). Each contractor also has a drill and blast bore to drive.

Earlier this year, a refurbished and rebuilt 7.2m diameter Robbins TBM, from the Karahnjukar project in Iceland, began excavating the single dewatering tunnel for the project. The tunnel is being excavated in advance of the parallel headrace tunnels on the project and is needed due to high inflows expected in the headrace bores, possibly up to 4,000l/s.

Herrenknecht has noted that the geology along the alignment of the bores comprises mostly (86%) limestone and the balance is sandstone. Its TBM has cutterhead power and torque of 4,900kW and 19,750kNm, respectively, and total thrust is 24,885kN.

Robbins TBM set for launch Jinping II, China

Snow storms and transport logistics proved a challenge to the entire project over recent months, including the wider, knock-on effects of the Sichuan earthquake. There were also delays in cavern excavation for the assembly. In addition, limited space on site required most TBM components to be staged 80km away.

Robbins erected the main beam TBM using its Onsite First Time Assembly (OFTA) method (*T&TI*, September, p29-31).

Following assembly, the TBM and the first three back-up gantries were walked forward approximately 200m to the launch chamber. A further six gantries and the conveyor were added, and the shield was launched on 18 September to begin driving for the final commissioning phase involving a 1,000m long test bore.

The contract requires that the shield achieves an average advance rate of at least 800m per month. The TBM's own two feeder conveyors have been designed to cope with wet conditions.

Steve Smading, Robbins' project manager, in noting that assembly was completed on schedule, said: 'Everything has gone remarkably well in retrospect. Of course we had problems, but our onsite assembly team was able to manage them as they occurred without adversely affecting the assembly process.'

Herrenknecht TBM at formal launch ceremony for Jinping II shields

Minova strides on bolt ambitions

Minova has added further to its European bolt capabilities with two more acquisitions that join the group that expanded last year with two buys and recently through a strategic pact with Atlas Copco.

The company has acquired steel bolt makers Berg- und Industrietechnik Arnall of Germany and Arnall of Poland, the latter also being a manufacturer of cable bolts and accessories.

In a statement, Minova said it was the largest supplier of rock bolts in Europe and is another step to its strategic goal of being a one-stop service for tunnelling and mining consumables.

Minova also recently made two other buys: US firm Excel, which makes speciality rock bolts and strata support accessories; and, Australian firm Strata Control Systems which designs, makes and supplies steel strata support products.

Financial details of the purchases were not disclosed.

Recently, a co-marketing deal was agreed between Minova and Atlas Copco to widen their respective markets for rockbolts. Atlas Copco customers would also have access to Minova's resins, grouts and related equipment (*T&TI*, September, p14).

As the ground control arm of Orica Group since its acquisition two years ago, Minova has made rapid headway into specialised steel products markets through purchases.

In 2007, it bought Czech firm Geobolt and French firm Cocentall's assets and sales.

Upper Rouge CSO cleared

Detroit's city council, feeling the heat from the state government, just made it before the late September deadline to approve the award of the contract to build the first, southern, section of the Upper Rouge combined sewer outfall (CSO) project.

Michigan state complained to the City Council about what it saw as a procurement hold-up. It charged there was a problem due to delayed environmental improvements and added there was also a risk of losing the finance in place, which would need other arrangements at greater cost to taxpayers.

The City of Detroit Water and Sewerage Dept (DWSD) is building the 5.75km long south tunnel Upper Rouge CSO as part of a larger project that will also see a north tunnel contract.

The CSO is to be excavated at a depth of 46m and will have a finished diameter of approximately 9.25m. The contract – PC-764 – also calls for construction of a 24.6m wide by 61.5m deep access shaft to launch the TBM, plus six connecting adits/deaeration chambers of varying lengths of 24.5m-443m and between 2.15m and 9.85m i.d. Proposals for initial and final linings were accepted in the bids.

DWSD received the bids in April but the state's environmental quality department complained that the committed award deadline of early August had passed, and posed problems. In turn, DWSD had been repeatedly complaining to the council but by late last month the contract had not yet been awarded. As a result, the state wrote a formal complaint from the environmental quality director, Stephen Chester.

The letter, of 24 September, warned that council 'inaction' threatened the entire project, which is described as one of the state's most significant water pollution schemes. Chester says that failure to decide would likely lead to a restart of the procurement process, months of delay for the contract and also the following contracts, possibly adding to construction price risk.

In addition, there was the risk of losing up to US$161M of debt finance on below-market, preferential terms from the State Revolving Fund if the contract was not awarded before the end of September. More delay would have resulted in taxpayers paying US$100M extra over 30 years.

TfL frustration on PPP budget

Transport for London (TfL) has expressed frustration at the apparent funding shortfall of more than US$1.77bn calculated by the PPP Arbiter in guidance requested prior to contract talks for the next phase of Tube Lines work, to begin in 2010. Tube Lines is responsible for the maintenance and renewal of the Jubilee, Northern and Piccadilly lines on the London metro network. The company began its 7.5 year contract in 2003 and the next phase is up for negotiation to cover work over the 2010-17 period.

The PPP Arbiter estimated the cost for the next 7.5 years of work was US$8.95bn-US$9.6bn. It said the analysis drew upon both firms' data as well as benchmarking with other metros. TfL, the owner of the tube network, asked in April for guidance and said the verdict of the 'rough estimate' that the envisaged works could cost more than was in the budget was an 'extraordinary circumstance'. It added that such a large funding shortfall should be met by the Government as it had introduced the PPP procurement system to the tube network.

TfL said that the difference in the cost estimates with the PPP Arbiter arose primarily in the grey areas of central costs, differential inflation and risk, and adding that it can't scale back the works.

Brisbane airport link JV places twin TBMs order

An order for two Herrenknecht TBMs has been placed by the joint venture of Theiss and John Holland for the excavation of Brisbane's Airport Link tunnel.

The contract value for the pair of 12.48m diameter shields is more than US$70M, the JV said. The TBMs are scheduled to be delivered to site in about a year and be launched in mid-2010.

The contractor is undertaking the design and construction of the project under a fixed-price, fixed term contract for completion by 2012.

The JV contractor has been hired by BrisConnections, which a few months ago awarded the contract to design, build, finance, own and operate the toll Airport Link by the state Government of Queensland. BrisConnections is a consortium of Macquarie Capital Group, Thiess, John Holland, Arup and PB, and will also build the Northern Busway (Windsor-Kedron) and Airport Roundabout Upgrade.

While TBM drives will be a major feature of the 5.25km long toll tunnel, the project calls for a total of nearly 11.8km of excavation which will also call on roadheader and cut and cover construction. The tunnels will be driven between Bowen Hills and Toombul.

The JV design and build contractor plans to use the two TBMs at Toombul to drive south, and roadheaders elsewhere. The contract package also involves construction of a 3km long road (half in tunnel) between Windsor and Kedron on the Northern Busway.

The airport link project is part of Brisbane City Council's TransApex plan, and will operate as a 6.7km long electronic toll road. The state Government said the airport link will cost US$2.6bn but the concession financing package means taxpayers will only have to contribute US$36M.

Jacobs wins SF's Bay Tunnel job

San Francisco Public Utilities Commission (PUC) has awarded Jacobs Engineering Group the construction management (CM) services contract for the Bay Tunnel project.

The contract is valued at US$18M and the entire water transfer project is valued at approximately US$270M. Bids were submitted for the CM contract in April, and the contract duration is 62 months.

Bay Tunnel will involve excavation of 8km of tunnel below the soft ground of San Francisco Bay for the water supply reliability scheme.

The 2.77m diameter tunnel will have a final lining of welded steel pipeline, and the project required construction of two major shafts.

In a statement, Jacobs vice president, Bob Clement, said: 'Our selection is testament to our capabilities to manage tunnelling in difficult ground conditions'.

Separately, the Commission recently approved construction of the New Crystal Springs Bypass Tunnel, another water transfer project which will be used to convey flows from the Sierra mountains. The project site will be in San Mateo County.

The 1,300m long tunnel, with a final lining of a 2.46m diameter steel pipe, is required to complement the existing bypass pipeline and improve the robustness of the water supply system against seismically-induced hazards.

Concerns over the robustness of the system were raised a decade ago by a landslide.

New Crystal Springs Bypass Tunnel project is expected to take three years to build and the estimated contracted value is US$55M-US$65M.

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Ecuador tunnel row ends with Odebrecht expelled

In an aggressive move that has shocked foreign infrastructure investors, Ecuador's President Rafael Correa has unilaterally ended all contracts with Brazilian construction giant Constutora Norberto Odebrecht SA. Correa has also seized the company's assets, issued arrest warrants against four executives – two of whom are said to have fled the country - and threatened to default on a loan of more than US$200M owed to Brazil's state development bank.

The action is the culmination of a drawn-out dispute over the 230MW San Francisco Hydroelectric Project, built by a consortium led by Odebrecht (*T&TI* June 2005, p25), which ceased power generation this June after just one year of operation. Conflict centred on the detection of major wear to one of the plant's turbines, necessitating repair of rotor blades, and fractures in the rock within partially-lined sections of the project's 11.5km long headrace tunnel.

The Ecuadorian government alleged faulty construction and procurement methods, demanding that Odebrecht pay for the repairs, return an early completion bonus and pay additional fines of up US$200,000/day in compensation for energy shortfalls. The consortium, which also includes Alstom and VA Tech Hydro, in turn alleged force majeure – but agreed to undertake the repairs while negotiations continued with the aim of re-starting normal operations by 04 October.

Much national media coverage of the situation ensued and in late September, less than a week before winning a national referendum that will facilitate significant socialist reform, President Correa issued an emergency decree to dispatch troops and take control of Odebrecht's projects. In addition to San Francisco, the company's estimated US$800M of assets include the Toachi-Pilaton and Baba hydro projects, the Carrazal-Chone water transfer project and a domestic airport.

While Odebrecht's employees continued construction and repair works under military guard, Correa banned four Odebrecht executives from leaving the country. Brazilian news agencies have since said that two of these executives fled the country, while it is known that the other two have sought refuge in the Brazilian ambassador's Quito residence to avoid arrest.

In response to Correa's actions, Odebrecht issued a statement on 01 October agreeing to meet the government's demands to complete repairs to the tunnel and electrical mechanical components regardless of culpability, as well as extend its guarantee on the project by one year and on the repairs by five. The company also stated that it has put a sum of US$43.8M in trust, to cover the early completion bonus and daily fines, until an audit by independent international experts decides whether it is liable for further penalties.

Despite this, Correa insists that Odebrecht will still be banned from operating in the country and is also threatening to default on a US$200M BNDES development bank loan used as finance for the San Francisco project. "In reality, it's money that went to the company, but appears as if it were a loan by Brazil to Ecuador," Correa said to state-owned Ecuador TV.

These decisions have shocked financial and legal commentators, such as Jose Valera, a Partner with leading international law firm King & Spalding LLP, who recently told the press: "Even if one wants to explain these actions as part of the president's politicking leading up to the September 28 referendum, the facts demonstrate a total disregard for due process and an alarming lack of legal security. I would anticipate that the Odebrecht expulsion will indeed further stifle private sector interest in upcoming energy projects in Ecuador."

Correa's aggressive 'state-centred' policies have curbed investment in key sectors such as oil and mining, which are even more threatened in the light of the current economic climate that is drying up financing for riskier emerging nations. "Correa thinks he has all the power to force investors to bow to his interests," said Jaime Carrera, head of the Quito-based Observatory of Fiscal Policy. "But what he is doing is scaring them away"

Falling world oil and metals prices, coupled with Ecuador's dwindling crude output and uncertainty over new mining laws, could seriously affect its fiscal position next year, experts say.

Tunnel pitched for Calgary airport

Efforts to secure a package of funding agreements at city council, provincial and federal government are about to be launched to enable construction of a strategic road tunnel at Calgary airport before the runway extension scheme gets fully underway.

The city council's proposed cut and cover tunnel would have three stretches that would pass below either the runway or taxiways. The stretch below the runway would be 180m long and at each taxiway would be 60m long, respectively.

The concept is for the tunnel is to have a box section sized to hold dual, three-lane roads plus a twin-track light rail. However, to help keep down initial costs it is envisaged that only one or two lanes in each direction would be opened initially and the light rail would not be installed until later.

Cost estimates for the tunnel are in the range of US$70M-US$92M, slightly over half of the entire anticipated cost of the new East-West expressway that would pass through the airport.

Local politician Jim Stevenson, the Alderman of Ward 3 in the city, has proposed an addendum to the council's existing "unfunded" plan for the tunnel project that would see the cost split three ways with the Province of Alberta and the Canadian Government. He plans to bring his proposal to the council in early November.

Should the council approve the plan he will then take it to the provincial government, and subject to success would then seek federal funding.

However, general grading works have already started at the airport in preparation for the main construction activities of the runway extension. While design work for the runway extension awaits environmental assessment there is only limited time for funding approval of the box tunnel initiative.

Zoomlion buys Cifa

China-based construction equipment manufacturer Changsha Zoomlion Industry Science and Technology Development Co and two partners have completed their acquisition of Italy-based Cifa.

The Milan-headquartered concrete equipment manufacturer is being acquired for a total of US$370M from its majority, private equity, owners led by Italy's Magenta.

A consortium of Zoomlion, Goldman Sachs, the Mandarin Fund and Hony Capital moved in June to strike the deal with Cifa. The acquisition gives a 60% holding to Zoomlion. Cifa needed to get Intesa Bank, with which it has had a debt agreement since 2006, to agree to the change of ownership.

As part of the acquisition process, and to serve its wider strategic goals in international markets, Zoomlion has set up ownership vehicles to serve its expansion plans. Zoomlion (Hong Kong) was approved to use US$150M to establish Zoomlion Overseas Investment Management (Hong Kong). The company is based in Changsha, Hunan province. Magenta and other private equity firms bought a controlling stake (72.5%) in Cifa two years ago.

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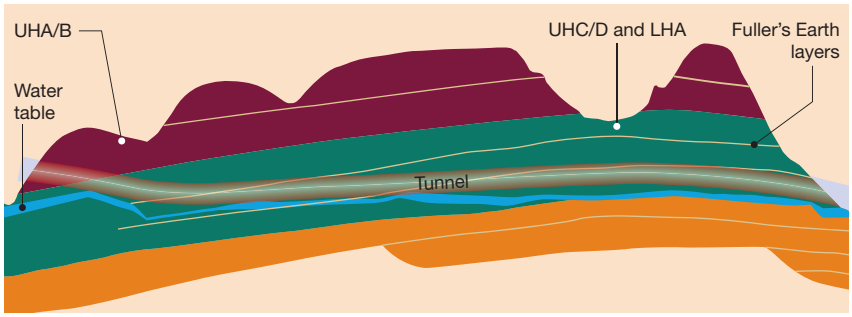
Hindhead hit

The A3 Hindhead twin bore tunnels, under construction in England, are taking forward the development of permanent SCL. Report and photos by contributing editor Patrick Reynolds

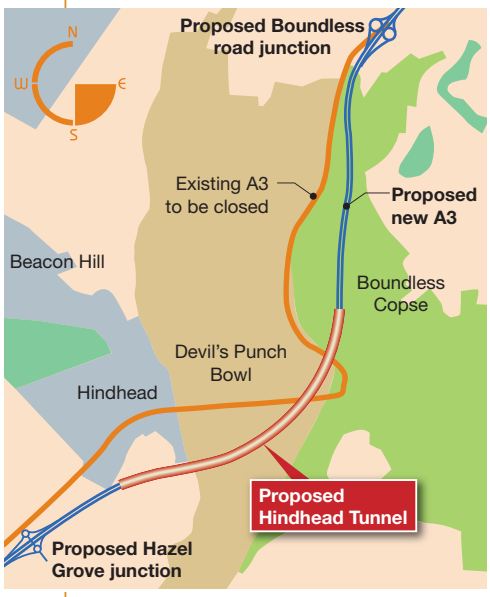


Above: Sandstone dominates alignment

In taking forward the UK's development of permanent sprayed concrete lining (SCL), the construction of the A3 Hindhead twin bore road tunnels, in southern England, is also presenting new approaches to flexibility at strategic and tactical levels, such as the use of Early Contractor Involvement (ECI), single gang working and adapting to materials cost inflation.

The need for programming flexibility was also set to be tested earlier this year when, just getting underway with the main drives from the North Portal, contractor Balfour Beatty found the ground to be poorer that expected. Fortunately, the conditions did not last. Over recent months, the excavations and permanent SCL placement have made good, and steadily improving, progress with the targeted first breakthrough on the prioritised 1740m long heading of the northbound tube set for the end of the first quarter of next year. By mid-2009 all major tunnelling work on both tubes should be completed.

As a major traffic congestion relief scheme by the Highways Agency (HA), the project calls for excavation below an area of protected natural beauty including the head of a valley called the Devil's Punch Bowl. The new route is to be operational by August 2011 (*T&TI*, June 2007, p23).



Left: Location of A3 Hindhead twin bore tunnels below area of natural beauty

Developing the solution

In October 2002, Balfour Beatty Major Projects began work on the ECI contract, which was on a Target Cost basis. The bid basis was 40:60 on cost-to-quality. Working with Mott MacDonald as a subconsultant, the contractor led the development and refinement of the scheme to planning and public enquiry stages, over 2004-5.

The tunnels have a reverse-curve alignment with the southbound tube, the longest drive being the 1790m bored section of the southbound tube. On completion, each tube will have a two-lane road and verges within a 10.6m finished width and height of 5.28m. The tubes will be linked by 16 cross passages. The client gives the project budget, discounted to 2002 levels, as US$580M. This figure includes HA's costs and tax. Construction works are budgeted at US$422M (2002 rates).

Early work, on design evolution, was cost-reimbursable, including for extra site investigation as requested by the contractor. Spend on geotechnical investigations totalled US$2.3M - 2002 rates, or 0.6% of construction costs, two-thirds of which was tunnel-related.

The geology is dominated by the sandstone of the Hythe Beds, and mostly above the historically-observed water table. The strata are variably sorted, highly glauconitic, variably bioturbated and cross-bedded sand and sandstones, and the alignment passes through the more competent units with UCS typically 2MPa-4MPa, though heavily fractured. The ground was known to be weaker at the south end of the tunnels.

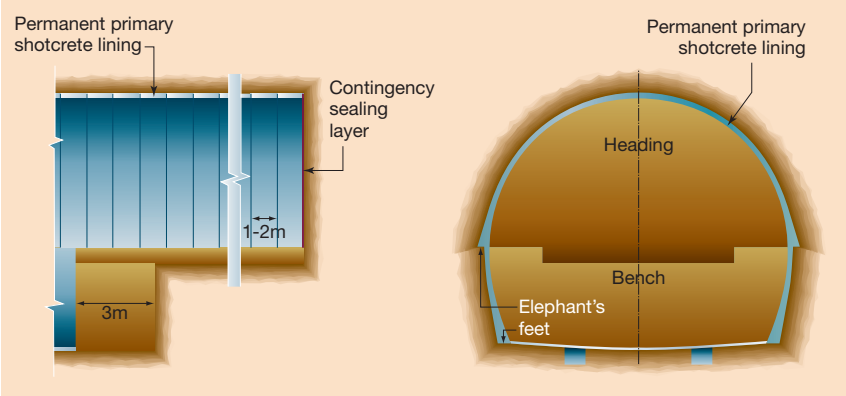
A key challenge was establishing the ground behaviour model in weak sandstone with up to 20% interbedded soil layers, and especially with the rock being weaker than typical when assessing strength and stiffness by empirical methods – which also don't allow for soil, especially in stiffness calculations. Site investigation included sonic, triaxial and pressuremeter tests – the latter proving the most reliable. Stiffness was estimated using a small strain stiffness model, and strength was modelled using a Mohr-Coulomb strain softening model.

Cover to the tubes varies significantly, most extremely from 16m-58m over only 130m. The vertical alignment is steeper at the southern end to minimise the length of drive through the weaker strata, and to maintain cover.

Project design and planning

Project development looked at merits of sequential excavation versus using a TBM, the latter having offered an alternative to avoiding vehicle emissions and generation of respirable crystalline silica from sandstone excavation. However, the advent of low emission diesel plant onto the market plus electric plant and the BTS guidance note on NOx exposure, out in 2006, presented the possibility for a modified, more economic, sequential lining and shotcrete support system.

The ground, and its relatively dry condition, has allowed the designer, Mott MacDonald, and the contractor and client to undertake the most extensive, and complete, use yet of permanent sprayed concrete – a design and construction approach that has made the most of major advances in the UK over the last decade,



Above: **Heading and bench excavation, and use of permanent SCL**

avoiding the need for lattice arches and steel mesh to help achieve permanent, stable ground support, whilst maintaining the required tunnel profile.

With an arch design, the lining is supported on wide footings – "elephants feet" – and the permanent SCL does not attract any tensile loads. Steel reinforcement is only therefore required at junctions, such as for cross passages. However, structural fibres are employed to provide a ductile lining giving safety to the tunnelling teams during construction. The permanent SCL will be made watertight using spray-applied waterproofing membranes specially developed for such applications. Like the sprayed concrete, the membranes are applied with robotic equipment.

The use of the permanent SCL system, as used at Hindhead, is its first major application in the UK, and in particular, a UK road tunnel. More generally, the system can be suitable for many applications in metros, rail and road tunnels where there is only modest water ingress and predictable ground conditions, which for example are not always found in Alpine tunnelling environments.

Construction gets underway

On project approval, in late 2006, the contractor geared up its small pre-construction operation led by project director Paul Hoyland and tunnel manager Roger Bridge. The payment basis moved to cost plus margin in relation to the target, and by mid-2007 major construction activities were underway.

In planning the works, which were to be neutral on cut and fill, a critical element is to hole through one heading to enable off-road spoil transfer from a cutting for embankment construction. Consequently, with the majority of excavation being pushed round-the-clock from the North Portal, the northbound tube has been prioritised and the wall-mounted conveyor will be kept active as bench excavation is finished. At the south end, the need to minimise disturbance for local people, progress is at a slower pace through adoption of a single, 12 hour shift and five day working.

Tunnelling began in February with four faces to be opened up, a pair at each end, but almost immediately there were ground problems at the north end. During portal cutting for the northbound bore, two fault zones were found, which were then met by the staggered southbound heading. Missed by boreholes, the undetected problem was due to an anticline with its near-vertical planes having fault zones, each 10m-20m long. Contingencies were explored, such as more excavation being done from the South Portal. Fortunately, the weak zones ended just beyond Boundless Valley and before the approach to the A3 at the Devil's Punch Bowl. Since then, the ground has been as envisaged, if not better, for excavation. By the middle of last month, the job had enjoyed good progress rates for almost four months.

A total of almost 47% of the heading in the northbound tube had been driven, the advances being 694m from the north end and 119m from the south. The comparable progress for the southbound heading was nearly 44% with 685m bored from the north end and 95m from the south. Given its importance to the Critical Path, excavation of the northbound heading is now more than 50m ahead of the southbound bore.

The greatest allowable settlement was calculated to be 23mm when passing beneath the A3. Actual settlement, so far, at the location is 13mm.

With greater priority for the southbound for bench excavation to be pushed – enabling it to be first to complete the full profile and proceed to secondary lining – that work is almost 22% complete compared to only 6% in the northbound tube. The earlier delay held back the bench excavations, which began in July and August, respectively.

Excavation

The heading excavation is nominally 11.6m wide, and the face area is 96m^2. Three Liebherr 944 machines are advancing the full face headings, two at the north end bores and one alternating between the bores at the south end. With dust generation to be minimised, ripper buckets were specified but as hard bands were also anticipated there were also breakers and cutters sourced. The excavators were required to meet a progress rate of 40m^3/hr and the ground is proving quite abrasive for the bucket teeth.

Face advances were seen as being 1m-2m. In the most of the drives, beyond the fault zone, the advance has settled at 1.5m-1.6m to suit geological behaviour and the optimum load distribution take-up by the primary lining. Excavation and installation of support for either heading or bench advances are typically working on four-to-six hour cycles, including one hour set time.

The job has three Sandvik Tamrock Axera 8 rigs, each with two drill booms and a basket boom – two rigs at the north bores, one alternating between the bores at the south end. The rigs are for probing the ground and also to install the 4m long, 32mm diameter, self-drilling, glass

Right: **Profile control is a key feature of the successful use of permanent SCL**

Above: **Steel pipe canopy installation at weakest, south end of bores**
Left: **Permanent SCL being applied**

reinforced plastic (GRP) dowels where needed. Combined with face sealing shotcrete, this is the extra support mainly used. In the fault zones, at the north end, there were up to 50 grouted GRP dowels installed at 250mm-300mm centres, which took up to three hours to install. In those stretches, advances reduced to 1m and grout stabilisation of looser ground was also done.

One rig is fitted with the Alwag Automated system for the heavier, pipe canopy installation at the south end. It also permits standard holes to be drilled for grouting or probing. The canopy is made of 140mm diameter, 12m long circular steep pipes in four sections. Typically, there are on average 25 pipes, but the number has varied from 19-31, less being required approaching rockier ground. The heading advances are approximately 8m, which is when the canopy is installed.

Geologists provide shift cover to inspect and log the faces, and help determine the most suitable support regime. The client's consultant on the scheme is Atkins, which is operating as HA Project Manager's Representative and Supervisor.

Tight survey control is vital to accurately excavate the profile and then construct the unreinforced, permanent SCL. At Hindhead, two systems are being used – a bespoke system being developed with VMT to examine 3-D control, and reflectorless total stations. The new system involves a total station tracking a prism on the excavator and which should, combined with feedback from inclinometers on the machines, enable software to execute real-time monitoring to help profile control.

The bores have extendable continuous conveyors, rated for 400 tonnes/hr, from Continental Conveyors. The initial plan was for them to follow the bench excavation but to minimise air pollutants they are behind the headings.

Each bore has a vent duct supplied by a twin 250kW fan set. Given the importance of limiting respirable crystalline silica there are four air filtration units of 25m^3/s capacity plus a smaller unit. Dust monitors are used to check eight-hour weighted average for exposure.

Support and linings

In each bore, a BASF Meyco Logica robotic spraying unit applies the permanent SCL in progressive layers to the crown and walls, and as a single mass for the elephants feet to avoid the risk of rebound entrapment or lamination. There are three units on the project – one more than initially planned, which was hired (unlike the others at the north end) as more work was undertaken from the south end.

The shotcrete has a required strength gain in line with the Austrian J2 curve, and strength of 40N/mm^2 but is achieving 50N/mm^2 - 60N/mm^2. The lining design is 200mm thick but can be up to 300mm thick where there is overbreak.

While the mix design is relatively standard, the advances that enable its application as permanent lining come in the superplasticisers and alkali-free additives, explains Ross Dimmock, Motts' technical director for tunnels.

With the non-structural benefits of fibres for application of the mix, the shotcrete was specified to have approx 30kg/m^3 of steel fibres. However, rising commodity prices has led to contractor to switch to sourcing structural PP fibres, though steel fibres will be kept onsite in reserve. A similar volume of PP fibres is used.

After the lining is applied, the heading is approximately 11m wide by 6.5m high, leaving just over 3.5m of bench to be excavated. The job has two Terex ITC Schaeff 210 excavators for bench and cross passages work.

Delivery and completion

Working across all faces, benches and lining activities is, unusually, a single gang. Their bonus is set on overall performance on the works. Ironically, the poor ground at the outset only helped to bed down the new, flexible working approach. Allowing for cross passage work, the gang advances the headings from the North Portal approx 10m/day (24 hours).

In the second quarter of 2009, work will move on to the non-structural secondary lining – again, 200mm in the design, but up to 300mm to allow for construction tolerances. Before then, a spray-on waterproof membrane (Masterseal 845A/855) will be applied, in effect creating a bonded "sandwich" of layers.

Watertightness has been a significant hurdle for permanent SCL linings, notes Dimmock. While being a relatively new approach, spray-applied membranes have a proven record to meet this need, and their use at Hindhead reflects a new design approach for SCL tunnels, and the provision of more economical, maintainable tunnels, he adds.

The overall design was also changed to make further use of the spray equipment and to benefit construction schedule and economics, resulting in the introduction of a 150mm thick SCL layer on the crown. Previously, the entire secondary lining was to be cast insitu but only the walls will be done this way, to give the aesthetics and smooth surface wanted. T&T

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At the mercy of the mountain

The Saint Martin La Porte adit is a key element of the exploratory works for the Lyon-Turin Base Tunnel. Eric Mathieu, head of Razel's tunnel design department, describes the extreme conditions encountered

The new Lyon-Turin High-Speed Rail Link will incorporate a 53km twin-tube Base Tunnel between the French town of Saint-Jean-de-Maurienne and Venaus in Italy. With construction due to commence in 2010, the largely EU-funded tunnel will become a key component of the Trans-European rail network, providing increased capacity for freight movement through the Alps.

As part of the early works for the Base Tunnel, two access adits are currently being excavated, Saint Martin La Porte and La Praz, with a further adit, Modane, already completed. These adits play a vital role in the investigation of conditions along the Base Tunnel alignment, as well as assist selection of excavation and lining methods.

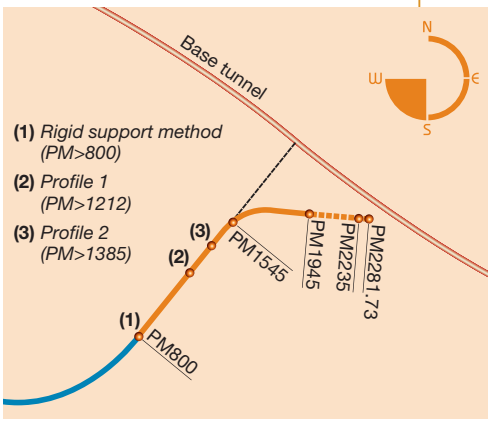
Despite being an investigatory heading, the 2200m-long Saint-Martin-La-Porte (SMLP) adit is a significant structure in its own right, with an excavated profile of 77m^2 to 125m^2 (for a final internal profile of 54m^2 to 63m^2), and will eventually provide construction access for the Base Tunnel.

The client, Lyon Turin Ferroviaire (LTF) awarded the construction works to a JV of Razel, Bilfinger Berger, Pizzarotti and GRA, which has a multiple role on the project: In addition to excavation, the JV also undertakes detailed analysis and mapping of the geological conditions encountered, convergence measurements, rock support design, construction design and proposal of methods - which are submitted for acceptance by the Project Manager (a JV of Egis Tunnels, Antea and Alpina).

Feeling the squeeze

Beginning on 01 July 2003, drill and blast excavation of the first 800m of the SMLP tunnel progressed steadily through landslide material then limestone, marly limestone and anhydrites. A full section heading advanced at an average of 155m a month, working 24hrs a day, five days per week.

However, as soon as the excavation encountered the carboniferous formation "Houillère Productif" (HP) at CH800, severe problems arose due to an extremely high degree of faulting and degredation of the



Above: **Fig 1- Route of the SMLP adit**
Left: **Convergences in Profile 1**

rock mass. Exceptional convergences, of more than 2m in diameter, caused tunnel linings to rupture and the tunnel advance to slow to a virtual standstill.

The carboniferous formation proved to be highly heterogeneous, disrupted and fractured, alternating between black schists, sandstones, clay-like shales and cataclastic rocks, interspersed with layers of coal.

Laborious excavation of the first section of the adit (figure 1) through the squeezing ground conditions of the HP (CH800-CH1545), under overburdens of 150m to 450m, was performed between 01 March 2004 and 06 April 2007. This required the study of different multiple excavation and lining techniques in order to refine methods that could cope with the extreme conditions.

Work on the second HP section (to CH2200), where overburden rose to 650m, began on 02 May 2007. By September this year, excavation had reached CH1930; current excavation rates are 32m/month working 24hrs a day, seven days per week.

Finding a way forward

An observational method has been adopted for monitoring the excavation works - based on continuous observation of the geology, deformations of the rock mass and linings, and immediate in-depth analysis of all data collected. This data is also subject to back analysis and numerical modelling, the results of which are used with caution considering the uncertainties of geomechanical hypotheses and the digital model's limit - particularly for taking into account the heterogeneity of the rock. Nonetheless, the calculations have been an indispensable tool for guiding the choice of lining methods.

To assist a flexible and adaptable approach to excavation, the JV established a task force of engineers from the worksite and from its designer Terrasol, assisted by geotechnical expert Prof Marc Panet. This task force, combining theoretical competence and tunnelling experience, works in close collaboration with the Project Manager and the following iterative process is adopted: implementation - observation, convergence measurement - back analysis - adaptation.

Understanding behaviour

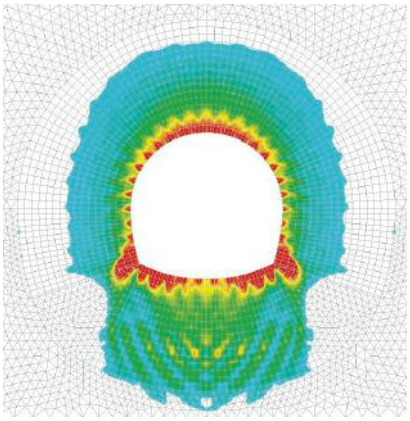
The first stage of excavation within the Houillère Productif (from CH800 to CH1385) began on 13 March 2004. Research and development of lining methods suitable for the exceptional conditions were undertaken, while remaining as close to the original scope as possible (optimisation of the 63m^2 horseshoe profile for the base tunnel).

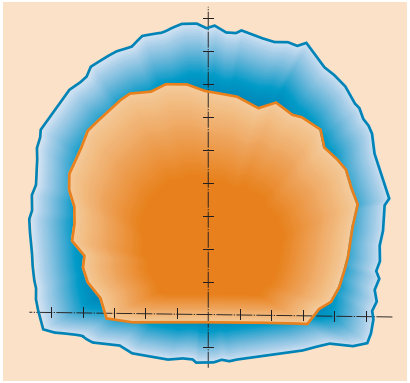
Geological variations were followed based on face mapping and probe drilling at the tunnel face (100m). The lining and the rock mass was extensively instrumented, with optical target monitoring sections placed every 5m and strain gauges equipping the majority of lining components. The extension of the excavation's zone of influence around the profile, in front of, and behind the tunnel face, was determined using 24m deep borehole extensometers around the profile and extrusometers installed 36m ahead of the tunnel face.

Persistence with rigid linings, until their

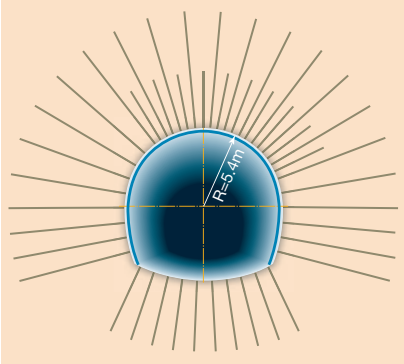
SMLP ADIT FACT FILE

Client: LTF (Lyon Turin Ferroviaire)
Project manager: Egis Tunnels/Antéa/Alpina
Client's consultant: Prof G Barla
Contractor: Razel/Bilfinger Berger/Pizzarotti/GRA
Contractor's engineer: Terrasol
Contractor's geotechnical expert: Marc Panet
Subcontractors: Fondazioni Speciali/GDTest
Adit cost: US$231M
Construction method: 780m D&B, followed by mechanical excavator with pick hammer
Construction finish: Mid 2009





Below left: **Fig 2 - 'Profile 1' lining design**
Above: **Fig 3 - 'Profile 1' numerical modelling results**
Right: **Fig 4 - Comparison of excavated profile (blue) and deformed profile (orange) for 'Profile 1'**



theoretical limit (at an overburden of 250m), allowed some time for further consideration of the problem of lining in highly squeezing rock. Pursuing excavation at the mean rate of 2m/day, full section excavation (88m^2) was carried out in 1m steps using mixed excavation techniques (excavator or drill and blast). The rigid lining composed steel ribs (HEB180) with invert arches and a 600mm shotcrete shell. These arches deformed as soon as overburden reached 230m, with plastification appearing quickly - at less than 20m from the face - and evolving rapidly.

Measurements recorded on the steel ribs showed load capacity was reached almost immediately after installation, exceeding the yield stress (275MPa). Different stabilisation attempts were undertaken, including reinforcement with 12m long self-drilling bolts and shotcrete, but this did nothing to halt the rupture process. The choice of a higher steel grade (E36) slightly extended the scope of this lining. But when overburdens of more than 250m were reached (CH>1215m) all rigid structures implemented at the face, such as continuous shotcrete shells or steel ribs, had to be abandoned.

Using worksite data, the geomechanical characteristics of the rock mass were re-evaluated through back analysis (Elastic modulus E = 500MPa, cohesion C = 200KPa and a friction angle Φ = 25°), this lead to the project's first flexible lining 'Profile 1' (Fig 2).

Profile 1 was implemented over a length of 170m with overburden of 250m to 350m. Full section mechanical excavation (93m^2) was carried out in 1m steps, with immediate dense radial bolting around the profile (figure 2), including the invert, in association with sliding ribs (TH 44/58). Bolting consisted of 10 x 4m long Swellex MN12 in the crown (for immediate action) and 34 x 8m long self drilling bolts (R32S, with an ultimate load capacity of 360kN) injected with mortar.

Originally, Profile 1 had a discontinuous 200mm thick shotcrete shell including 4 or 5 x 300mm wide longitudinal slots. However, less than 10m from the face, the slots completely closed and the shell, which became rigid, evolved toward rupture. It was rapidly abandoned. Profile 1 was therefore completed with a shotcrete ring designed to close the section and block deformations. The moment of closure (distance from the tunnel face) depended on the evolution of convergences and the achievement of a stable state or progressive stabilisation.

Calculations made with an elasto-plastic model and Mohr-Coulomb failure criterion provided for an extension of the plastic zone of about 6-8m and convergences about 1000mm in the short term. Follow-up on-site measurements of Profile 1 confirmed the anisotropic character of the deformations. The amplitude of the convergences after 145 days at a distance of 60m from the tunnel face exceeded 2m, this increased with overburden. Convergence rates varied from 50-30mm/day at the face with 50% of total deformation taking place in the first 20m.

Analysis of measurements over sufficiently long excavation shutdown periods (15 and 20 days) showed that the distance of influence of the tunnel face was about 50m. Beyond this, deferred deformations were characterised by a continuous and regular, almost linear evolution without any sign of stabilisation - the convergence rate remained about 7-8mm/day. The excavation's zone of influence extended 12-15m around the profile and developed rapidly, with 80% taking place less than 5m from the face and maximum extension measured at 20m.

The 'plastic' zone, considering rock mass failure criterion is reached as soon as radial deformation is greater than 5 x 10^{-3}, rapidly developed in the first 20m after the excavation and then continued to progress versus time. At 60m from the face it extended 8m-12m around the profile, reaching a maximum at the invert and the right hand side. Extrusion of the face remained limited; involving only the first 4m of the tunnel advance and with amplitude at the face not exceeding 50mm (figure 5).

All this data was used by Terrasol in a new back analysis to re-evaluate the rock mass characteristics (E = 100MPa; C =150KPa; Φ = 25°). Yielding ribs (TH) significantly improved safety in the tunnel and regularity of the excavation was controlled with the use of forepoling. But they had no effect on the evolution of the deformations. After 600-800mm of diametric convergence (reached 30m from the tunnel face), they stiffen and enter plasticity. The extent of convergences and absence of stabilisation meant this zone had to be reprofiled (by a thickness of 1m) and covered with an 800mm thick concrete ring 60m from the tunnel face (figure 4).

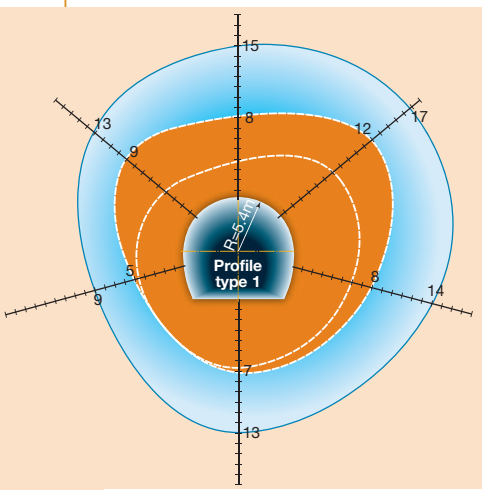
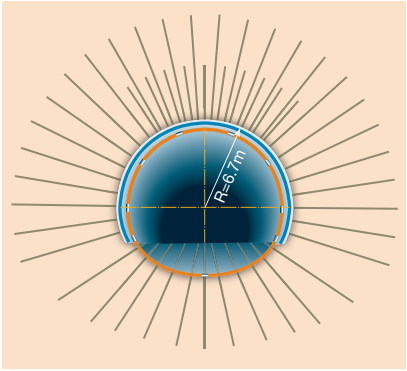
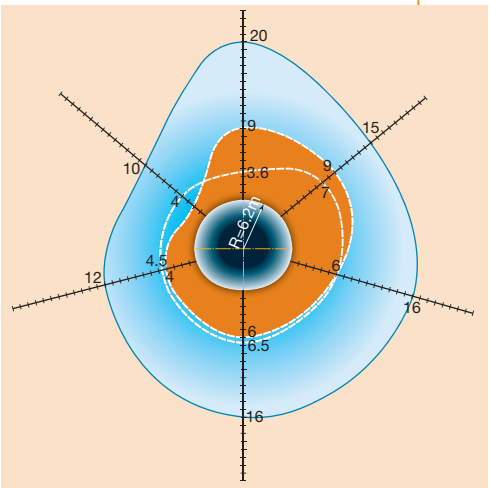


Fig 5: **Extension of deformed (blue) and plastified (orange) ground for 'Profile 1'**

Major convergences of Profile 1 and the new Profile 2

Solexpert's hiDCon compressible concrete elements





Left: Fig 6 - Profile 2 lining, with Phase 1 marked in blue and Phase 2 in orange
Right: Fig 7 - Extension of deformed (blue) and plastified (orange) ground in Profile 2
Below: Fig 8 - Profile 2 numerical model with Phase 1 (left) & Phase 2 (right)

As the convergence rate was still high at the time of concreting, this induced rapid loading of the ring. The maximum stress recorded was about 17MPa and it evolved at a rate of 0.6MPa/100 days after 1 year. The average rate of excavation during this time was about 18m/month due to the many reinforcements and interventions.

New lining for Houillère Productif

Experience from the first HP section provided a better understanding of the rock mass. HP's behaviour follows a complex viscous-elasto-plastic model, which is yet to be completely defined. Owner LTF awarded the modelling studies of the future Base Tunnel to Prof Giovanni Barla (*T&TI* May p15).

Monitoring of the adit is being carried out using a simple elasto-plastic model. Creep is taken into account by activating degraded rock characteristics in concentric crowns of growing thickness incremented at each new calculation step until an 8m thick crown is obtained in the final step (concrete ring). The degraded rock's cohesion is considered to be zero and Young's modulus is also low. Anchors are partially and progressively deactivated according to plastification.

A new lining method was studied by the contractor to respond to the specific problems at the SMLP – it was necessary to release rock mass stresses near the work face, by accepting key convergences before controlling deformations, to avoid excess degradation of the rock and reduce lining stresses. Exceptionally high convergences and the extension of the traversed zone make the adit an extremely rare, if not unique, case - and there are many approaches for defining lining methods, including varying experiences or different empirical, and sometimes cultural, approaches. The JV therefore consulted several design firms to benefit from different philosophies and experiences:

The solution proposed by Müller+Hereth was based on a two stage heading-bench excavation, in 2m steps, with a flexible lining composed of anchors and shotcrete installed at the work face: A crown of 22 x 9-12m long self drilling bolts (roof and walls) spaced every 1m; a thin flexible shotcrete shell (100mm thick) with arches spaced every 1m; closure of the invert 50m from the face with a 200mm shotcrete layer.

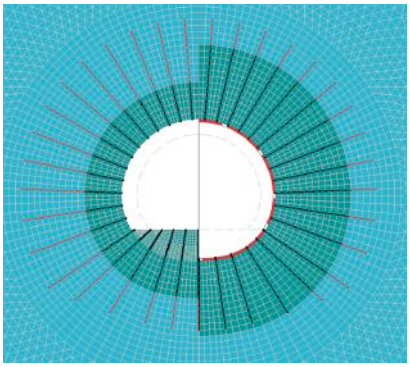
The solution proposed by Geodata SpA consisted of a full section advance, in 2m steps, with a relatively rigid lining designed to rapidly block deformations. Proposed reinforcement was 75 x 24m long fiberglass bolts (VTR); with rigid steel ribs installed at the face (double IPN20) and spaced every 1.25m; a 300mm thick shotcrete layer and 8 x 6m-8m long Swellex MN24 bolts in the side walls. The section is closed less than 15m from the face with a 500mm thick concrete invert and the shell reinforced with a 200mm shotcrete layer.

Prof Kalman Kovari (Zürich Federal Polytechnic School) and Prof Arno Thut (Solexperts) proposed the use of relatively new materials. For stretches of tunnel through squeezing ground on Switzerland's Gotthard and Lötschberg Base Tunnels, Solexperts developed a highly compressible concrete element named hiDCon.

The solution finally adopted for the SMLP was an amalgamation of these approaches, incorporating experience acquired on the worksite. "Profile 2" (see figure 6) is a multiphase lining (three phases), which progressively rigidifies as the distance from the face increases.

The advance and the ground around the advance (2m thick crown) is reinforced with 120 x 24m long fiberglass bolts (providing 15 usable metres) to try to reduce the evolution of convergence in the first 20m behind the work face (amplitude, homogenization):

Phase 1: A flexible lining installed immediately after excavation, which follows



rock mass deformations and absorbs 30% of the total convergence (600mm max).

Phase 2: A secondary semi-rigid lining, installed 30m from the face, over the flexible lining. It consists of a closed invert arch capable of supporting 400mm diametrical convergences while providing sufficient confinement to control deformations. To create this yielding shotcrete lining, Solexpert's hiDCon elements are installed within the shotcrete shell. The elements can deform at a pre-set, constant stress level of 50% and after this load is reached, resistance begins to increase until a final value is achieved (v = 0, initial resistance of 8MPa, final resistance 15MPa.).

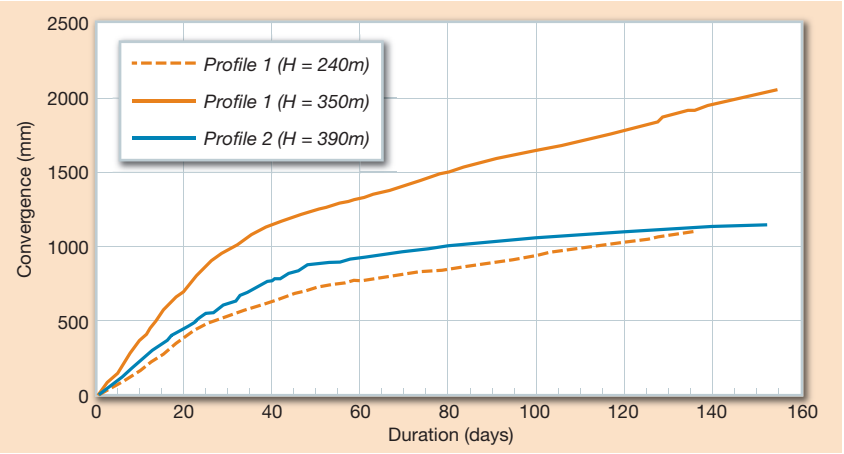
Phase 3: A final 1m thick rigid lining is cast 80m from the face, which blocks deformations and closes the section.

Full section excavation is carried out via mechanical excavator in 1m steps, with the three lining phases progressing concurrently. The horseshoe profile was abandoned for a near-circular profile, which was enlarged to take convergences and the new lining thickness into account. The new excavated section is 125m^2 for a final profile of 54m^2.

The new solution required reorganisation of logistics and resources: Increasing working hours to 24/7; increasing labour by 30%; abandoning the crusher and conveyor for loaders and dumpers; procurement of a 5m long mobile concrete form; and a rig to install the fiberglass bolts (an EGT 7100 equipped with 2 x 27m long booms).

Profile 2 was implemented from CH1385 under an overburden of 350m to 450m. The deformations on the Phase 1 flexible lining are still anisotropic and the amplitude of the diametrical convergences vary between 600mm and 800mm. The rate at 30m from the face is 17mm/day. These values remain close to those measured on Profile 1.

Phase 2's semi-rigid lining significantly slows down convergence. The amplitude is 400mm and convergence at 80m from the face is 1mm/day, while it was 7mm/day with Profile 1. Although stabilisation is not obtained, a slight inflection can be observed on the convergence curves. Therefore total convergence (compared with Profile 1) is reduced by 50%, even with an increased overburden of 50m (figure 9). The excavation's distance of influence remains in the order of 50-60m. The extension of influence around the section varies from 12-16m. It rapidly develops at less than 5m from the tunnel face. The "plastic" zone remains large - 20m from the tunnel face. It extends between 7m and 10m around the section and undergoes an increase on the order of 20% (compared with Profile 1) linked to the increase in the overburden height (+25%).



Above: **Fig 9 - Characteristic convergence experienced with each lining profile**

Using Profile 2, excavation is progressing steadily at an average rate of 32m/month. The multi-phase lining is well suited to the unique conditions of SMLP and provides control of the convergences behind the face. The experience acquired is decisive and has provided some good lessons:

i) Pre-consolidation does not have any discernible impact on the evolution of convergences. When they exceed 600mm in Phase 1, or in the case of high anisotropy, the first rib has to be removed and reprofiling done before the semi-rigid lining can be installed. In this highly squeezing rock mass and under heavy overburden, convergences at the tunnel face cannot be controlled.

ii) The semi-rigid lining (Phase 2) allows good homogenization of the deformations and control of convergences. The secondary lining (Phase 2) still has to be installed 25m from the work face. Beyond convergences of 400mm (compactness limit of the hiDCon blocks), the shotcrete shell scales at the interface with the hiDCon blocks, leading to their expulsion, which reinforces the choice of a multi-phased lining.

iii) Bringing Phase 2 closer to the face does not affect total convergence (Phase 1 + Phase 2). The reduced amplitude obtained at the end of Phase 1 is compensated by an increase in the evolution of convergences during Phase 2. Ultimately, the total amplitude is exactly the same. These observations allowed validation of the results obtained on the digital models.

iv) The concrete ring loading curves show a significant drop in stresses (50-60% compared to those obtained with Profile 1). Over an equivalent period (130 days), the maximum stress measured in Profile 2's final lining is about 5MPa, while it reached 14MPa in the concrete ring of Profile 1. Over this same period, the loading rate plunged from 5MPa/100 days (Profile 1) to 0.8MPa/100 days (Profile 2). However, this stress gradient in the midterm remains in the same order, at approximately 1-1.5MPa per year.

In order to circumvent the Houillère Productif at the base of the adit, LTF modified the alignment of the SMLP (see orgininal in black on figure 1). As of CH1600, conditions have better, but deformations, although much less, still remain significant.

Conclusions

Along the 2280m of the SMLP, the Houillère Productif accounts for little more than 1400m and has a max overburden of 650m. The Lyon-Turin Base Tunnel will encounter similar conditions for a length of 1000m-1200m under overburdens of 550m-700m.

Calculating elasto-plastic behaviour with the Mohr-Coulomb failure criterion is, to a certain extent, limited in the domain of large deformations, as observed in the SMLP adit, and does not take into account the time factor required to estimate deferred deformations of the rock. Back analysis of convergence data allowed the creation of a short- and long-term rock behaviour model. The long-term stresses will be better evaluated by continuing measurements for several years on the final lining. Utilisation of a viscous-elasto-plastic model that takes time factors into account (Lemaître's Law) allows a better correlation with convergences measured in the adit. Terrasol is currently implementing this model in the finite difference modelling software FLAC.

The solution required for these conditions presents major and unexpected problems, which adversely affect costs and deadlines. As a result, the SMLP contract's conditions required the need for frank and in-depth discussions based on the analyses shared between parties. T&T

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Slide solution for Barcelona's Line 9

Rolando Justa, tunnel department director for Acciona Infraestructuras, describes the curved slide of a 12m diameter Herrenknecht EPBM and its back-up equipment through the open cut Sagrera Station box on Barcelona's new metro Line 9, in Spain

Stacked configuration of the new metro Line 9,

Fig 1: **Route map showing the alignment of Barcelona's new metro Line 9**

Above: **Inside view of the concrete segment plant, with rolling moulds and water steam curing chamber**

The US$3.2bn metro Line 9 is one of Barcelona's most significant infrastructure projects in recent years. When complete, the new driverless subway line will be the longest in Europe, with an overall length of more than 44km. The new line runs across the city connecting Badalona and Santa Coloma de Gramanet, in the north-east, with Zona Franca and the airport, to the south-west (figure 1). Construction of the line is divided into four sections (or Lots) based on the typology of the ground and, in total, involves the use of four TBMs - one 9.4m diameter and three 12m diameter machines.

Due to the lack of surface space in the city, a single large tunnel with a double-deck rail track configuration has been selected for the line. This allows station platforms to be located within the running tunnel itself, allowing surface disruption to be limited to access shafts in highly congested areas rather than large station box structures.

A deep tunnel alignment, at an average depth of 35m below ground, was selected for a combination of reasons, allowing the alignment to pass below existing underground infrastructure, through better ground conditions, but primarily to reduce the risk of surface settlement as much as practically possible.

The tunnel lining consists of pre-cast concrete segments. Each ring has an outer diameter of 11.7m and is formed of six segments plus a key. The width of the ring is 1.8m and it has a thickness of 400mm. This Universal ring allows horizontal and vertical curves greater or equal to a radius of 300m.

Concrete mix design

Manufacturing of the segments is undertaken in a factory located in the "Torre de Corb" industrial estate, in Balaguer (Lleida). The manufacturing process is automated with rolling moulds and fixed workstations, which facilitates high productivity and an excellent level of quality.

According to the Spanish Code EHE, the concrete used for segment manufacture is not considered conventional. Two characteristics make it "high performance" concrete. Firstly, is the concrete's ability to exceed 50N/mm^2 strength at 28 days. The second is the use of a combination of steel bar cages and steel fibers for reinforcement.

Prior to the comencement of segment manufacturing for Line 9, the Structural Technology Laboratory of Barcelona´s Civil Engineering School carried out a study to

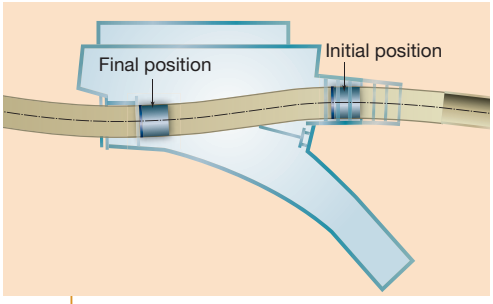

Fig 2: **Sliding alignment for the TBM at Sagrera shaft**

optimise the concrete mix design. The test-based design process adopted by the Structural Technology Laboratory involved three main stages: Definition for the cement paste composition; the granular aggregate mix optimisation; and the cement paste verification in the concrete. Once defined, a toughness study was undertaken for the concrete mix reinforced with steel fibers.

Ultimately, the pre-cast segments for this section of the Line 9 project, consisted of HA-45/P/20/IIb-H concrete. In addition, 25kg/m^3 of steel hook fibers (0.75mm diameter and 50mm long) is added to the concrete mix, to give an equivalent flexural strength of 2.9N/mm2 after 28 days.

TBM sliding operation

The UTE Gorg Joint Venture selected a 12m diameter Herrenknecht EPBM, at the time the largest machine of its kind, to excavate through the soils from Gorg Station to the open cut box of Sagrera Station (Lot IV) and from Zona Franca on the eastern branch of Lot II to Zona Universitaria Station.

On October 2007, ALE Heavylift Iberica, in cooperation with the Tunnel Department of Acciona Infraestructuras SA jointly started to look at solutions for sliding the TBM across Sagrera Station following breakthrough. The main challenge was the need to negotiate two opposing curves, of 285 and 300m respectively, within the station box (figure 2) and avoid disassembly and relocation of the back up equipment using heavy cranes.

Typically for this kind of slide, a concrete cradle and thrust frame would be employed, however due to the curved path this method was deemed unsuitable. In addition, the casting, assembly and demolition of additional reinforced concrete structures would be required in order to lift and relocate the back up equipment.

After several meetings a solution was reached based on an existing skid system that could be modified to suit the site conditions and restrictions.

In December 2007, the 1500t TBM shield and its back-up (equating to an additional 1000t), was skidded a length of 80m, successfully negotiating the two curves.


The Herrenknecht shield is moved across the station

Equipment

The slide was carried out by means of standard ALE SKS5000 skidding equipment modified to suit the site conditions. Hydraulic skid shoes moved over PTFE (Teflon) blocks that were incorporated into steel skid tracks. The system included a 500t skid shoe incorporating a 500t capacity cylinder with a working stroke of 620mm. On top of this cylinder a pivot afforded longitudinal and transverse movement, which allowed adjustment to the curved path.

The force required for skidding the structure was generated by hydraulic push-pull cylinders, which were an integral part of the skidway. Each horizontal jack had a total pushing capacity of 64.3t and a pulling capacity of 33.9t. The units were coupled to the skid shoes by means of a pin-construction. Centralised diesel-driven power packs generated the hydraulic power required for operation of the skid shoes' and push-pull units' hydraulic cylinders.

Skid shoe stability was designed with a side-force of 20t - up to a maximum of 10% of the vertical load on the skid shoe involved. Four skid shoes were employed for the operation. These were arranged under special brackets welded to the TBM shield at positions previously approved by the TBM manufacturer.

The skid tracks were placed at a distance of 5580mm from the axis of the TBM, with 11700mm between the two tracks. The tracks were positioned on concrete slabs and fixed using specially designed anchors.

Once the TBM arrived at the station, preparations began with the welding of brackets onto the shield and installation of the final portion of the skid tracks. A 960mm high x 640mm wide and 6m long beam was installed over each pair of skid shoes and


Assembly of one of the rolling supports for the back-up

Above and right: **The TBM sliding process underway in Sagrera shaft**

positioned under the brackets that had been welded to the TBM.

In this position the beams were welded to the brackets and the weight of the TBM was transferred to the skid shoes by means of the two rear pushing jacks and two front pulling jacks. The shield and backup were then slid simultaneously through the station box. To assist this task a special device that allows the back-up to be rolled across the rails was designed by Acciona Infraestructuras SA and Herrenknecht's technical department.

Once the TBM reached its final position, the shield was again transferred onto concrete supports using the jacks and the skidding system was removed.

The entire sliding operation took eight days and was considered a complete success. T&T

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Setting up for 2nd Avenue subway

Preparation is underway for the TBM launch pits and first stations on the Second Avenue subway project in New York. Report and photographs by technical journalist Adrian Greeman

It has been a long time coming, an underground metro line for Second Avenue in Manhattan, New York. However, finally, work is underway at street level for the start of boring, and excavation of the first stations, mostly in deep tunnel and hard rock. A TBM is currently being reconditioned for the tunnel contract and the launch pit excavated.

The need for a new line has been clear for over a century when efforts were first made to build the subway line. The great high rise offices and shops making up the famous city skyline now have an even more insatiable demand for workers and staff, but getting to workplaces on the city's East side is an overcrowded nightmare at peak times. The city's 24-hour Subway system moves millions in the Downtown and West mid-city areas, but on the East side there are problems; here there is only one transit line running North-South, unlike the West side which has several routes.

The four track Lexington Avenue Subway, with two stopping lines and two express lines, is packed at rush hour - driving daily ridership to over 1.3M. Commuters, pouring into Grand Central Station and from the downtown connections to Brooklyn and New Jersey, frequently have to wait for three or four trains before being able to get on.

"There is no real relief from cross-links either," explains Anil Parikh, programme manager for the client, the Capital Construction division of New York's Mass Transit Authority (MTACC). "The strong grid system of the city runs north to south primarily and though east west links have been built since, the two sides are cut off by Central Park at mid-town level."

In the early 20th Century the transit needs were partly met by an elevated line running parallel to Lexington on Second

Left: Existing utilities are a problem for the 2nd Avenue Subway

Avenue, but this stopped operating in 1942, and was later demolished. A scheme for a subway line had already got started in the 1920s but was stymied by the Great Depression; money allocated at the beginning of the 1950s was needed for system maintenance overall.

Finally, in the early 1970s, construction started on some elements of the new line, primarily underground like much of the earlier system. But in New York financial troubles hit again and the few isolated sections that had been constructed, between Pell and Canal Street, 99th Street and 105th Street, and between 110th and 120th Street, were left high and dry.

They are still dry, because of routine maintenance, but are now a constraint on the alignment of the latest version of the line, which began in 1999 with a concept design by Parsons Brinckerhoff. The older sub-street level sections mean that new line must rise up at those points to make use of the existing structures.

Moving the line forward

A three strong group, including DMJM Harris, AECOM and Arup, took the design forwards when the go-ahead was given in 2006 and began detailed design.

"East-West connections are also a limit on the design since you must either go over the top or underneath them," says David Caiden, Arup principal and tunnel engineer for the project. But to go underneath means going very deep since the cross lines were mostly constructed later than the longitudinal routes and were built deeper he says.

The full project is to be a twin-track line running down Second Avenue from 125th Street in Harlem to Hanover Square in the financial district, near the tip of Manhattan Island. The total 13.6km is divided into four phases, the first in the mid-town area to be completed by 2015, and a second running to 125th that will use the most of the already built sections. The two downtown phases have neither specific nor outline dates yet.

Surprisingly, the first section is not the one making most use of the already completed sections. Instead it will be deep tunnel running from 96th Street to 63rd Street. The reason, explains Caiden, is that this allows the first phase to link into the Broadway line, which turns as a cross-city route and links to the relatively new 63rd Street line (see figure 1). The 63rd Street line crosses the East River to Queens, making use of another previously mothballed project, the 63rd Street immersed tube tunnel, built in the 1970s.

In effect, phase one of Second Avenue will be an operational branch of the

Above: **Cramped working conditions above the alignment**

Broadway line for its first years. This means it will connect into the full subway system, rather than be simply a stand alone shuttle system, and be able to achieve a high ridership from the outset. It also means the line can initially use existing maintenance depots on other lines, saving costs.

The US$4.3bn phase one will primarily be funded by the New York state, with money voted through in 2005. A little City funding supplements this and an additional US$1.3bn of Federal transportation funds was confirmed in autumn last year.

Minimal disruption

Deep tunnel was chosen where possible for fairly obvious reasons, says Caiden. It avoids the enormous disruption of cut and cover work at the surface and the need to get through the utility cluttered ground of the city. Helpfully, this section of the route is in the centre of the island where the hard schist that famously supports Manhattan's skyscrapers is close to surface, rather than the softer ground found further south.

Early discussions suggested going off the traditional under-road routing altogether, to allow the entire alignment to go deep, but this fairly radical notion for New York was ruled out; it meant abandoning existing tunnel, and would have involved far more property purchases than currently required.

Even for the first phase, mainly in deep tunnel, there is cut and cover work to be done, in particular for the TBM launch pit. This is being constructed at 92nd street as the first part of an excavation running north to 96th Street, which will be used for construction of the 96th Street station.

Just at this point, the Manhattan schist dips deeper anyway, while the line has to be fairly close to surface to connect into

Above: **Fig 1 - Project map with phases**

phase two finished sections (figure 2).

A joint venture of New York contractor Schiavone (recently acquired by Spain's Dragados), Shea and Skanska is building the starter pit as the first stage of an overall US$337M tunnelling contract for the two drives to 63rd street. The remainder of the station cut and cover and construction of the station box within will be let separately.

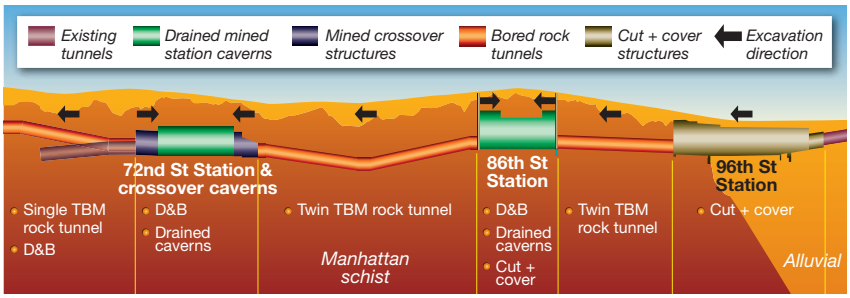
The twin 6.8m excavated diameter drives will be driven with a refurbished Robbins TBM, currently being reconditioned by Herrenknecht at a Schiavone work yard.

The TBM's first run will take it 2400m with a curve at the end to link into an existing "bellmouth" extension at the F-line station, and the other just 1540m following its pull-back and re-launch.

"The reason for the shorter second drive is programmatic," says Caiden. The two intermediate stations are being built as underground rock excavations from surface shafts to avoid city disruption, an important consideration in an expensive city area "with more lawyers living in it per square yard than anywhere else in the world," as one project engineer joked.

That will mean underground blast work.

Above: **Attempts to keep disruptions to a minimum in effect**



Above: **Construction methods along Phase 1**

But New York safety regulations are very stringent and would require evacuation of the TBM tunnels during most blasting, disrupting the drives.

"There is an advantage in passing through the stations and removing much of the rock with the TBM first," says Caiden, "but set against the time constraints – both stations are on the critical path – it is just not worth it." The tunnel's remaining length will be done as drill and blast within the station contracts.

For similar reasons the concrete lining of the tunnel, to a final internal diameter of 6.08m is to be cast insitu.

The value of using deep excavation for the stations is already becoming apparent on the initial works for the launch pit. Finding, identifying and diverting services in the street has already taken six months longer than the eight months expected, delaying the diaphragm wall work.

"The services issue is a real headache," says Kirit Mevawala, construction manager at the site for MTA Capital Construction, the projects arm of the Mass Transit Authority. "There is just such a lot of utility relocation, involving dealing with multiple companies and suppliers."

Caiden, with extensive worldwide experience, says he has never seen so many complex services in the ground "and surprisingly, here in Second Avenue, which is a broad thoroughfare, which you would have thought had room for plenty."

Service lines of all sizes are looped and twisted over each other, every new installer seemingly to "simply work around what was already there, leaving a tangle like spaghetti," says Mevawala. All sizes of line are present from large gas and water mains, sewers and big electrical cables to high-tech fibre optics and modern telecommunications.

But because it is New York there are also unusual and older services too, including pneumatic tubes for inter-office document transport, the famous steam heating pipes, and some obsolete unidentified pipes. Problems are compounded by asbestos used to insulate some pipework.

For each service there is a third party to deal with, says a somewhat harassed Mevawala, though fortunately most of the lines have identifiable owners. But in New York there are complications, typically with rentable service ducts which have a main owner such as the Empire City Subway, but are then sublet, and on occasion even sub-sub-let.

The excavation also has to deal with the old foundations for the elevated line, mostly brick and rubble. But a much nastier surprise was a large subterranean solid brick wall going down 6m or 7m, apparently a retaining wall for an old brewery building, which had to be removed.

Currently work is closer to finishing on the second, east side, of the street and diaphragm wall and secant piling is beginning for the 30m deep excavation. This will be 250m long and 23m wide enclosed primarily in a diaphragm wall through the glacial silt and clay deposits and keyed into the rock head, though a small part of the periphery will be constructed in secant pile wall.

Mevawala says the tunnelling machines should be assembled and ready to launch in about June of next year.

The drive should then move steadily, though there will be further constraints from issues like mucking out. Not surprisingly, in commercial and residential districts lorry movements are restricted; no night moving is allowed and numbers are limited in the daytime. "It means the machine will be driving around 20m a day, though it could handle perhaps over 30m," says Caiden.

Station activity

Meanwhile a station contract will be moving on too. The three block-long cut and cover station work follows on to a cut and cover contract, which will use much of the excavation for the tunnel launch but extending north one more block.

Stations will be twin level with track below and a concourse above, like many recent metro systems, and use centre platforms to save space. "They will have an open airy feel, which will be a big contrast to the existing system," says Caiden.

Two more stations are required at 86th and 72nd Street, these are deep mined contracts. Shafts for the work will be excavated as part of the initial tunnelling contracts though separate mining contracts will be let later.

At 72nd Street Station there will be a cavern 104m long with an approximate depth of 15.7m below Second Avenue to the crown. The cavern itself is 13.5m deep. Current plans are for a 21.54m width containing two tracks and a central platform, a change from an originally envisaged three track station with an additional side platform.

The 86th street station is also 312.5m long, though it is slightly deeper at about 17.2m. Again it will be 14.5m deep inside with a 23m cavern width.

All the stations will feature modern glass and steel transparent entrances at street level and the overall feel will be similar to modern stations in systems built elsewhere in recent years. T&T

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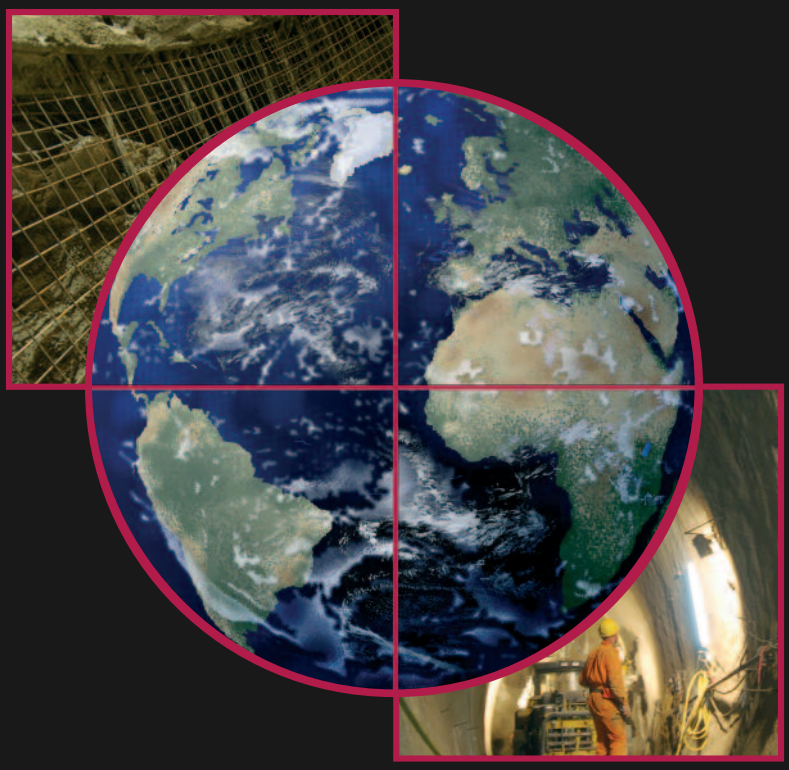

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Products

Vibration monitor

Instantel has recently introduced the next generation of the Minimate range of instruments. The Minimate Pro4, a four-channel unit, is designed to monitor with one triaxial geophone and one air overpressure microphone while the Minimate Pro6, a six-channel unit, is designed to monitor with two triaxial geophones.

The Series IV Minimate Pro4 and Minimate Pro6 monitors have been designed to withstand the harshest environments. Their rugged design includes a cast aluminium case, fully sealed top panel, and non-corrosive, impact-resistant connectors. These monitors feature improved RF immunity and EMC performance exceeding CE class B requirements. An enhanced user interface includes intuitive menus, larger backlit display, and multiple font sizes.

With the real-time operating system, there is uninterrupted event monitoring ensuring zero dead time between events. The flexible sample rates from 512 to 4,096 offer programmable record times of one second to more than one hour, and the expansive memory offers a capacity for over 8000 one-second events at a sample rate of 1024S/s.

Ethernet communications allow high speed data transfer of recorded events, uploading of setup configurations and live data display on your PC. Important features like Auto Call Home remote monitoring and an enhanced Histogram Combo recording mode are also included.

Instantel
Web: sales@instantel.com

Thread design

In response to demand for a stronger, more powerful drill string, Rockmore has developed the XR32 thread design for tunnelling operations.

The company claims the XR32 connection provides stability at the thread end, reducing stress on the thread connection. The innovative ContactZone design provides stronger rod support, increased rigidity and added strength to minimize rod bending. This means less wear, higher precision collaring and straighter holes. Better bit guidance means better hole precision and drilling accuracy. Less reflex vibration means less wear and increased thread life for both bits and rods. Smooth integration, increased equipment life combined, and better performance are what Rockmore says it has provided with the XR32.

Rockmore
Web: www.rockmore-intl.com

Subway shotlining

The Dominican Republic Transport Reform Office (Opret) is constructing the second underground rail system in Caribbean. Shotcrete Technologies Inc supplied equipment and Shotset 250 Accelerator to the first such system in Suan Juan, Puerto Rico, being constructed by the Kiewit/Kenny/Zachary JV, and is supplying contractor Nicobar with ST Alkali Free Accelerator and a Shot-Tech Robotic Arm. The project calls for 14km of tracks and 16 stops, 10 underground.

Shotcrete is being applied an average thickness of 6" thickness using 2-4% ST Alkali Free Accelerator. Average rebound is less than 5%. Completion of the first section of the billion dollar project was expected as *T&TI* went to press.

Shotcrete Technologies
Web: www.shotcretetechnologies.com

Wheel solution

Scheuerle's "Beaver" is a wheeled vehicle designed to take pre-fabricated segments to the tunnel's lining erection zone allowing a more flexible use of the driveway inside the tunnel. This way it is possible to have other vehicles drive on the same track, and react flexibly to modification of the transport roads during the construction stage.

The system consists of a total of five vehicle combinations, each a combination of two vehicle units. Both the vehicle units are connected by an "intelligent" towing and pushing rod which recognizes the force relations of the two vehicles and acts as a regulator if deviations occur. This ensures that the vehicle driving ahead always remains as "master" in the towing position, and that the following "slave" remains in a towed position, in spite of equal drive power. This way, high driving stability of the multiunit vehicle is achieved, important at speeds of up to 30km/h inside the tunnel.

Each vehicle unit is equipped with a Diesel engine, powered with 127kW at 2000Upm.

The machines are highly safety concious, with each cab constantly under excess pressure, so that if smoke develops inside the tunnel the cab remains smoke-free. The driver this way stays in a position to safely control his vehicle in emergencies. The low-exhaust emission Diesel engines are equipped with a special air conduit and filter system that prevents accumulation of pollutants inside the tunnel.

The vehicles are equipped with an electronic all-wheel steering, advantageous when docking at the loading and unloading stations. To achieve as much flexibility as possible, the vehicles are designed so they can be driven as a single vehicle, two or even several vehicles.

The vehicles has a safe carrying capacity of 100 tons.

Scheuerle
Web: www.scheuerle.com

International Arbitration - part 2

T&TI's contracts and disputes correspondent, Paul Cullinan of Plus 3 consultants, concludes his introduction to International arbitration

In the previous article we outlined some of the general principles relating to international arbitration, the nature of arbitration agreements; controls on the conduct of arbitration; standard rules and ad hoc versus institutional arbitration. Continuing that theme, this article focuses on the various steps leading up to the start of, and stages during the course of, an arbitration.

Whilst close attention must be paid to the rules under which arbitration is conducted, the stages of an international arbitration will generally be as described as follows.

Before proceeding it is well to explain some of the terminology used in arbitration. The party making the claim is the Claimant, the party receiving the claim is the Respondent. These terms are usually adhered to even when a Respondent makes a counter-claim in the same arbitration, i.e. the use of 'counter-claimant' and 'counter-respondent' would be just too confusing. A typical counter-claim in an engineering contract will arise where a Claimant says 'you delayed me and therefore I claim additional time and money', the Respondent says, 'yes, you were late but for reasons of your own making which actually caused me losses that I now claim from you'.

To avoid confusion, as sometimes there maybe a panel of three arbitrators, the generic phrase of 'tribunal' is often used in the arbitration law of many countries and arbitral rules.

Notice Of dispute and Appointment of Tribunal

For there to be an arbitration there must be a matter of dispute or difference. It will usually be self-evident what are the issues between the parties through the course of discussions and even the exchange of claims and rebuttals before the beginning of the formal process. Once these reach a point where one side or the other believes they cannot be resolved short of arbitration then the rules will normally prescribe the form and content of a notice of dispute, these should be followed closely. Typically the notice of dispute will include the name of the parties and identification of the contract and arbitration agreement and short description of the matters in dispute.

The drafting of the notice is a very important step and must be undertaken with care, the notice will circumscribe the matters which can be taken forward to all following stages of the arbitration, if a matter is left out it cannot, without further agreement of the other party and sometimes the tribunal, be brought into the arbitration later on.

Either separately or, depending on the rules, included with the notice of dispute the claiming party will serve upon the other a notice to concur in the appointment of an arbitral tribunal. In many instances this notice may give several names for an intended Respondent to select from, with a proviso that if there is failure to reach agreement within a certain period then the intended Claimant will go to the body named in the arbitration agreement for them to appoint a tribunal. In the event that there is no agreement and no appointing body named in the arbitration then in most jurisdictions the courts can be asked to step in and appoint a tribunal.

If the Respondent intends to lodge a counter-claim of the type outlined above then it must also give notice of its intention to do so at this stage. Many rules have particular deadlines by when such a notice of counter-claim should be given, for example before the appointment of the tribunal. A Respondent party therefore must pay close attention so as not to miss out on being able to have its own counter-claims included within the same arbitration.

Where the tribunal is to be comprised of a panel of three arbitrators the usual procedure is that each party will name its preferred tribunal member, there may be some right of reasonable objection to this choice, the third member is then selected by the two party-selected members of the tribunal. It is stressed that even though party-selected all members of the tribunal are expected to act impartially as between the parties.

Preliminary meeting

Following the appointment of the tribunal a preliminary meeting is held, principally this is to set down the timetable for the remainder of the stages of the arbitration but can include addressing various issues and procedures that may not be defined in the rules, a preliminary meeting will normally last two hours at the most.

These procedural and technical aspects aside, the preliminary meeting is usually interesting because it will be the first time that personnel from the respective parties will have seen the tribunal 'in action', it may also be the first time the parties' protagonists have seen each other for some time, possible previous acrimony being replaced in this new formal setting with an air of awkward politeness.

Following the preliminary meeting the tribunal will issue Orders For Direction, this is a roadmap for the all the following stages of the proceedings any changes to it will have to be agreed with the other party and the tribunal.

Exchanges

The exchanges are the documents or 'pleadings' used by each side to set out its case and its objections to the case put by the other side. Assuming a case with an element of counter-claim the sequence of these exchanges will be, Claim (by Claimant); Defence and Counter-Claim (by Respondent), Reply and Defence to Counter-Claim (by Claimant) and Reply to Defence to Counter-Claim (by Respondent). In some cases these exchanges will continue with Rejoinder, Surrejoinder, Rebutter and Surrebbutter although such extensive sequences are discouraged in modern arbitration proceedings and are quite rare. Where they are allowed they will likely be restricted by the tribunal to a particular point which may assist clarification.

Again reference will need to be made to the rules for what is required here. Some rules call only for 'Points of Claim' (and Defence, etc.) these will be a rather terse and surprisingly short statements of the legal and/or contractual basis for the various claims or defences as well as a brief outlining of the facts to be relied on with little, if anything, by of supporting documentary evidence. Other rules will call for a Statement of Claim or Statement of Case, these will tend to be a more fuller and more narrative in nature and may include much of the documentary evidence to be relied on by party in support of its case and can run to several, or in some cases several tens of lever arch files.

The central purpose of the exchanges is to set out one's case with sufficient clarity and detail that the opposing party knows what the case is it has to answer. A claim should set out with precession the legal basis on which a claim or part of a claim is relying on, known as the cause of action. Very often this will include at least one and often several 'alternative' bases of claim on a particular point, for example a claim that the completion date is no longer enforceable or in the alternative that an extension is due to fix a new completion date.

A defence should address each and every allegation contained in the claim in turn. Each allegation should either be 'admitted' or 'denied', if denied reasons for the denial should be given, again modern arbitral practice does not look kindly on 'bare denials'. In this way a tribunal can work its way through each of the legal basis and facts relied on to begin to distil where there may be common ground and where there is real dispute, the latter will in turn lead to a more focused review of the evidence put forward (adduced) by each side to enable the tribunal to decide on the point one way or the other, in turn leading to conclusions of overall liability.

Discovery of documents

Discovery, often referred to now as 'disclosure' is the process whereby each party has the opportunity to seek copies of documents that may not be available in the normal course of business. This is the scary bit of arbitration, all those internal memos, reports and meetings with previously private comments that, 'this project is going to the dogs and it's our own fault'; copies of correspondence received with expletives handwritten in the margins, evidence of all those little cameos of skulduggery (we once found a copy of our foreman's lost diary in discovery of the opposing party's files!), all are bound to be laid open to the eyes of the opposing party and the tribunal.

Again modern arbitral practice has developed to seek to curtail what could, and had developed, into a free-for-all in discovery whereby each side was allowed free access and demanded copies of any and every document or type of document, which could remotely have anything to do with the cases set out in the pleadings.

These excesses became known as 'fishing expeditions' and are now discouraged. Instead each party should give lists of documents that are within its 'power possession and control', each side will be given reasonable access to the others documents but are encouraged to be more selective as to the particular, or class of, documents it requires to see. Objection can be made to requests for documents on the grounds that they are not relevant to the case, in which circumstance the tribunal may have to rule on whether certain documents should be provided.

Some classes of documents are not bound to disclosed these are documents which attract 'legal privilege'. These will normally include exchanges between a party and its legal representative, which are made 'in contemplation of litigation'. There is a habit of heading certain documents 'privileged', but it is the content and nature of a letter that will be finally determinative of whether or not it is privileged.

Witness statement and expert reports

As noted above there will be certain primary facts upon which there is dispute and must be proved by the party asserting them, this is done by way of witness evidence. This evidence is sub-categorised into witnesses of fact, that is those persons actually involved in the project and more particularly those aspects disputed, and witness of opinion, that is experts.

Each witness gives their evidence, what is known as their 'evidence in chief', they are then subject to cross-examination, which is the much-feared grilling by the opposition's lawyer and finally re-examination by one's own side's lawyer, this can be a damage limitation exercise to remedy some area where the opposition may have 'scored points'.

Again in modern arbitral practice to save time (and cost) at the hearing the witness evidence in chief is given in written form and exchanged prior to the hearing. These

"IT MAY ALSO BE THE FIRST TIME THE PARTIES' PROTAGONISTS HAVE SEEN EACH OTHER FOR SOME TIME, POSSIBLE PREVIOUS ACRIMONY BEING REPLACED IN THIS NEW FORMAL SETTING WITH AN AIR OF AWKWARD POLITENESS"

"THIS IS THE SCARY BIT OF ARBITRATION, ALL THOSE INTERNAL MEMOS, REPORTS AND MEETINGS WITH PREVIOUSLY PRIVATE COMMENTS THAT, 'THIS PROJECT IS GOING TO THE DOGS AND IT'S OUR OWN FAULT"

will still be subject to cross and re-examination in the hearing as before. To save time and narrow issues to be dealt with at the hearing experts may hold meetings where they can at least try and see where they do agree on certain aspects. For each matter agreed it is something less for the tribunal to decide on, again with consequent savings in time and cost.

A difficult concept for any client is for them to understand that even though a party has appointed and is paying for an expert an experts primary duty is to impartially inform and assist the tribunal. This can lead to a difficult relationship between clients and experts, but it should be realised if an expert's evidence is seen to be too partisan, it will be discounted by the tribunal in any case.

The hearing will much anticipated and for the first several days well-attended by even quite senior management from both parties. There are few 'Perry Mason' moments in a construction/engineering arbitration and in a long hearing that interest will rarely be sustained and as the days and indeed weeks go by attendance becomes much more sparse. The atmosphere is quite formal, the tribunal being addressed as 'sir' or 'madam' and much of the 'my learned colleague' exchanges between parties' lawyers.

The hearing will be by far the most expensive part of the process, as one looks around the room and sees the 'meter running' on the assembled tribunal, lawyers and experts, not to mention the venue hire and stenography service, the bill for sandwiches and coffee alone can run into thousands!

Most of the hearing will be taken up with working though the list of witnesses of fact and opinion in the manner outlined above, in addition there may be some time taken in dealing with legal arguments where the lawyers will try and illuminate and persuade the tribunal as to the applicability of certain points of law to facts as revealed.

The award

After the hiatus of the hearing it is a waiting-game for the tribunal to weigh all the matters it has heard and draft its award. This will normally be a very weighty document in its own right giving detailed reasons for reaching the conclusions it has.

At the end will be the 'operative part' of the award, that is a formal statement of who owes what to whom. The habit upon the receipt of an award therefore is to open the envelope and skip straight to the last page when one can either punch the air in delight or let one's heart sink as one works out how to break the bad news to your client.

It is these moments which highlight what a high risk approach to dispute resolution arbitration can be, having entrusted your hopes to a third party in this way there will always be a winner and a loser. T&T

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GPR grout check on Shanghai Metro

At this year's North American Tunneling (NAT) Conference, Fengshou Zhang, a PhD student at the School of Civil & Environmental Engineering, Georgia Institute of Technology, won the Student Competition with his paper on the use of ground penetrating radar to determine grout quality during shield tunnelling in China

In order to evaluate the effectiveness of the grouting treatment before tunnel operation, a non-destructive testing method using ground penetrating radar (GPR) was proposed to detect the grout thickness behind the lining segments of metro lines in Shanghai, China. GPR has shown to be a viable approach due to the fact that: 1) the detecting objects (concrete segments, grout and soil) were at a depth of one meter or less; 2) dielectric parameters of all the materials can be obtained from the laboratory; 3) the contrasts in the dielectric properties among these three materials were large enough; 4) only the boundary between the grout and the soil needed to be found since the concrete segments had a known even thickness of 0.35m. Three GPR frequencies 250MHz, 500MHz and 1GHz were used in the field tests in Shanghai Metro line 9. Among them, frequency at 500MHz showed the most promising results.

Introduction

The metro lines in Shanghai, China are growing by 20km per year. By 2010 a rail network over 400km long will be completed. The metro lines have been constructed by shield tunnelling where TBMs were employed to excavate in the soft silty clay layer at a depth of 12-32m[1].

In shield tunnelling construction, after the lining segments have been placed, backfill grout is injected to fill the gap between the lining segments and the soil[2,3]. The grout can strengthen and stabilise the tunnel structure and make the tunnel waterproof.

Since tunnels are longitudinally flexible and subject to dynamic loads, uniformity and quality of the grout have a great influence on the long-term settlement[4,5]. From the beginning of the operation in 1995 to 2001, Metro line 1 in Shanghai had settled a maximum of 160mm[6]. The current settlement control method has been to carry out grouting once more where settlement had already occurred. To improve the effectiveness of the grouting treatment before the operation of the tunnel, a geophysical non-destructive monitoring technique has been used to obtain the distribution of the grout behind the lining segments[7].

Ground penetrating radar (GPR) is a geophysical method that uses radar pulses to image the subsurface[8]. The transmitting antenna radiates short pulses of the high-frequency radio waves into the ground. When the wave hits a buried object or a boundary with a different dielectric constant, the receiving antenna records variations in the reflected return signal.

In this paper, GPR is proposed to detect the distribution of the grout behind the lining segments of the shield tunnel. In practice, GPR detection can be carried out along the testing lines as shown in Figure 1. Such an approach to evaluate the grouting effectiveness was viable since: 1) the detecting objects (concrete segments, grout and soil) were at a depth of 1m or less; 2) dielectric parameters can be obtained from the laboratory because the components of all the media were known; 3) there were large enough contrasts in the dielectric properties among these three materials, which was the key to GPR detection; 4) only the boundary between the grout and the soil needed to be found since the concrete segments had a known thickness of 0.35m.

In this work, the dielectric constants of the grout and soft silty clay soil at the frequency of 0-1.5GHz were first tested using the coaxial probe technique in the laboratory. The dielectric constant of the concrete segments was then determined indirectly based on the electromagnetic (EM) wave velocity obtained by measuring the travel time of the EM waves in the lining segments bounded by a metal plate. Finally, GPRs with three frequencies 250MHz, 500MHz and 1GHz were used in the field tests of grout detection on Shanghai's Metro line 9. Among them, frequency at 500MHz showed the most promising results.

Dielectric constant

Dielectric constant ε is a number that relates the ability of a material to carry alternating current to that of vacuum. The relationship between dielectric constant ε and the electromagnetic (EM) wave velocity v can be expressed as[9] (equation 1):

$$v = \frac{C}{\sqrt{\varepsilon}}$$

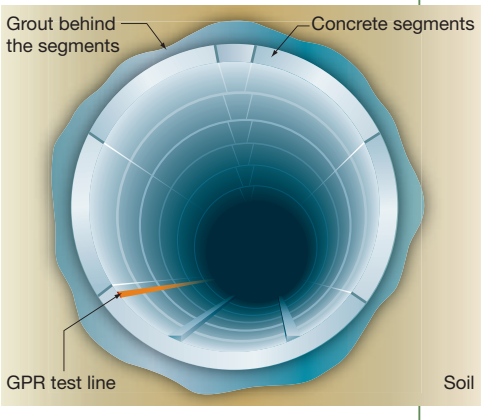
where C is the velocity of the EM waves in vacuum.

The reflection coefficient of the EM waves is defined as[9] (equation 2):

$$R_i = \frac{\sqrt{\varepsilon_{i\text{-}1}} - \sqrt{\varepsilon_i}}{\sqrt{\varepsilon_{i\text{-}1}} + \sqrt{\varepsilon_i}}$$

where R_i is the reflection coefficient of the EM waves propagating from medium i-1 to medium i, and $\varepsilon_{i\text{-}1}$ and ε_i are the dielectric constants of media $_{i\text{-}1}$ and $_i$, respectively. If the absolute value of R_i is greater than zero, meaning there is a dielectric property difference between the two media, reflection

Below: Fig 1 – Cross section of a shield driven tunnel



will then occur on the boundary.

The dielectric constant ε not only determines the EM wave velocity v of a certain medium, but also governs the reflection characteristics of the boundary. Therefore, the dielectric constants of all detecting materials are needed for a proper analysis of the GPR data.

Grout and soil

The grout of interest was the double-slurry previously used on Shanghai metro tunnels. Components of Slurry A and Slurry B are shown in Table 1. During the tunnel construction, Slurry A and Slurry B were to be transported by different pipes, and then mixed in situ before being injected into the gap between the segments and the soil.

The soil in the layer where the shield tunnel was excavated was soft silty clay. The soil samples were tested in the laboratory right after they were delivered from the construction site. The unit weight of the soil sample was about 18kN/m³. The soil samples contained about 50% water content and the void ratio was 1.43.

The dielectric constants of the grout and the soil were determined directly using the coaxial probe technique[10,11]. A HP8753E network analyser was used to obtain the reflection coefficient data at the frequency of 0 - 1.5GHz (figure 2).

Grout with a total weight of 3kg was first prepared according to the mix shown in Table 1. The slurry was then cast into a 70×70×70cm mould and kept in a curing box with humidity and temperature similar to those in the field. The surface of the samples were polished prior to the tests to keep a tight contact between the sample surface and the probe.

The testing procedure was slightly different between the grout and the soil. While the probe was placed flush with the grout sample surface, the coaxial probe was inserted directly into the soil sample due to its high water content.

Table 1: Components of slurry A and slurry B.

Slurry A (kg)				Slurry B (L)
Water	Cement	Stabilizer	Bentonite	Sodium Silicate
803	376	3.2 (L)	78	120

Results

Dielectric constants at the frequencies of 250MHz, 500MHz and 1GHz were given in Table 2. The dielectric constant was frequency-dependant and decreased as the frequency increased. Due to the decrease in water content, the dielectric constant of the grout on the fourteenth day was much smaller than that on the third day. On the third day, the dielectric constants of the grout and the soil were very close. Therefore, the reflection coefficient at the soil/grout boundary would be nearly zero, which was not suitable for the GPR to detect the boundary between layers of the grout and the soil. However, contrast in the dielectric constant between the grout and the soil appeared to be large enough on the fourteenth day. The dielectric constant of the grout was now 61% of that of the soil at 250MHz. As a result, we chose to perform GPR detection fourteen days after the grouting treatment.

Lining segments

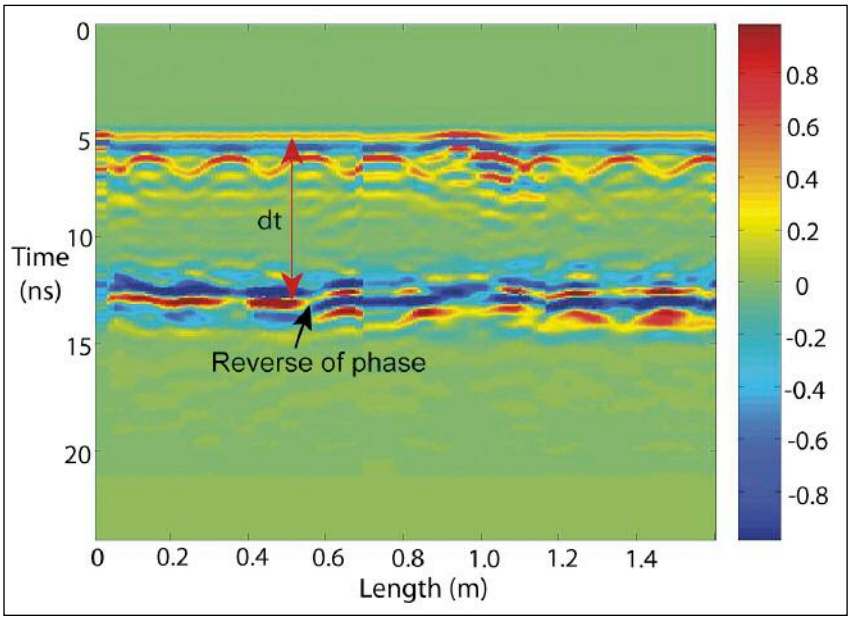
Due to the bulky nature of the lining segments, the coaxial probe method can no longer to be employed to determine the dielectric constant. An indirect method based on measuring the EM wave travel time through the segments was used instead. Since the segments were manufactured with a constant thickness of 0.35m, the EM wave velocity and consequently the dielectric constant can be determined if the EM wave travel time through the segment was known. In order to accurately compute the travel time from the GPR data, a composite system with a metal plate stuck onto the outer surface of the lining segments was constructed so as to cause absorption and strong reflection of the EM waves. When the EM waves propagate from one material with a high dielectric constant to another with a low dielectric constant, the reflection coefficient will be positive, according to equation 2, and no phase reversal will occur. Conversely, when the EM waves travel from one material with a low dielectric constant to another with a high dielectric constant, then the reflection coefficient will be negative and phase reversal can be observed.

Frequency at 1GHz

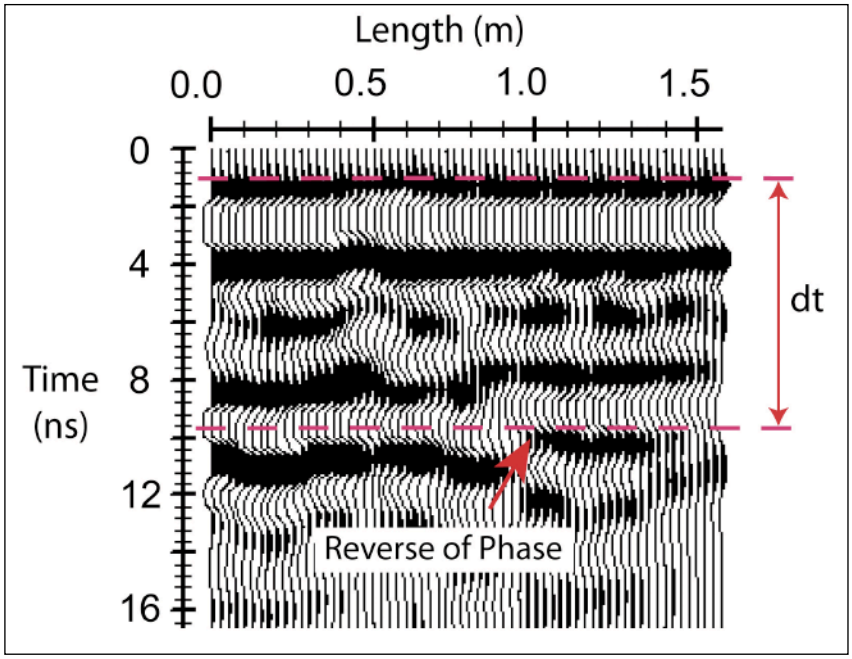
A Noggin 1GHz GPR was first used to determine the EM wave velocity in the concrete segment. The GPR detection was

Table 2: Dielectric constants and the EM wave velocities of the grout and the soil at the frequencies of 250 MHz, 500MHz and 1GHz.

	250 MHZ		500 MHz		1 GHz	
	ε	v (m/ns)	ε	v (m/ns)	ε	v (m/ns)
Grout (3rd day)	34.5	0.0512	32.0	0.0530	26.5	0.0583
Grout (14th day)	22.5	0.0632	18.0	0.0707	16.5	0.0738
Soil	37.0	0.0493	34.0	0.0514	32.0	0.0530



Above left: Fig 2 – EM wave velocity of the lining segments Right: Fig 3 – 1GHz data for the EM wave velocity test of the lining segments



Above: **Fig 4 – 250MHz data for the EM wave velocity test of the lining segments**

carried out along the inner surface of a real lining segment used on Shanghai metro lines (see figure 3). The metal plate was placed on the right side of the test area.

The 1GHz GPR data was processed by MATLAB with proper gain. Strong reflection due to the existence of the metal plate can be clearly identified from the test results shown in figure 4. The test result also showed a turn point of phase reversal along the line of strong reflection, an indication of the boundary between the segment and air (or the metal plate). The time difference dt, around 7.5ns, was the travel time of the EM waves in the segment. Since the thickness of the segment was known as 0.35m, the EM wave velocity of lining segments at the frequency of 1GHz was 0.0933m/ns. It then followed from equation 1, the dielectric constant was 10.34.

Frequency at 250MHz

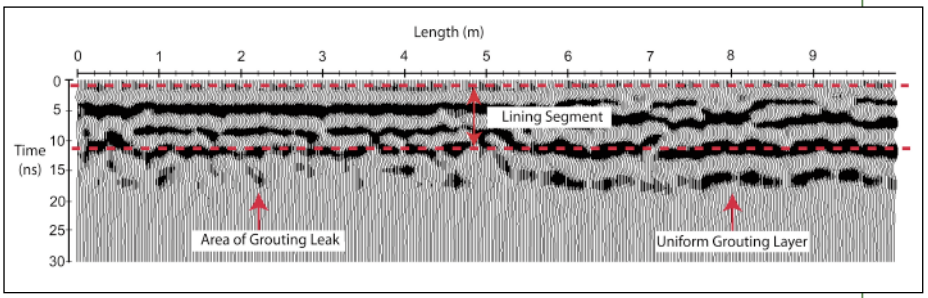
Noggin 250MHz GPR was also used to test the EM wave velocity of the segments. The principles of the EM wave propagation should not be affected by the frequency used in these tests. Similar results were expected. In this test, the metal plate was now placed on the left side of the test area.

The 250MHz GPR data, processed by the software PIPEGPR 2.3[12], was shown in Figure 5. The time difference dt was the travel time of the EM waves across the segment, around 8.5ns. The EM wave velocity of the lining segments at the frequency of 250MHz was about 0.0824m/ns. Consequently, the dielectric constant was 13.25. The dielectric constants of concrete segments from these experiments were about twice the common values, possibly due to the fact that the lining segments used in the shield tunnel were cast using the high strength cement.

Field tests in Shanghai Metro line 9

Field tests were carried out in Shanghai Metro line 9 between Xuhui District and Songjiang District with a length of 30.28km at the first phase of construction. The project started from October 2002 with all works finished by the end of 2007. The outer diameter of the shield tunnel was 6.2m. The thickness and width of the lining segments were 0.35m and 1.2m, respectively. The tunnels were excavated by the EPBMs with the excavation rate of 5 - 8 rings per day.

Noggin GPRs with frequencies of 250MHz, 500MHz and 1GHz were employed in the field tests. The parameters of equipment were shown in Table 3. The 250MHz GPR data was processed by the software PIPEGPR 2.3 (Xie and Zhao, 2003), and the 500MHz and 1GHz GPR data were processed by MATLAB.



Right: **Fig 5 – Data from 250MHz GPR field test**

Frequency at 250MHz

Grout detection using the 250MHz GPR was carried out on 25 July, 2006, one month after the grout had been injected. The data over 10m is shown in figure 5. It can be seen that no obvious reflection occurred on the left side of the domain, while on the right side strong reflection suggested an even layer of the grout. The detection results were consistent with a journal that recorded leakage of the grout in the tail of the TBM, when excavating at the length 0-5m.

At the frequency of 250MHz, dielectric constant of the grout on the fourteenth day was 22.5. In this case, we assumed the dielectric constant value of the grout at one month to be about 20. On the right side (length 5-10m), the travel time of the EM waves in the grout was around 5.0ns (round-trip), which suggested the thickness of the grout to be about 16.7cm.

Frequency at 500MHz

The 500MHz GPR detection was carried out on 05 August, 2007, after the grout had been injected for about twenty days. The processed data of 3.3m was shown in figure 6. From the test results, we can find the obvious boundary between the segment and the grout at the time around 9.5ns.

The outline of the three segments can also be distinguished due to the discontinuity in the GPR data caused by the joint between the two adjacent segments. Also we can find the reflection at the time of around 15-16ns in figure 6 due to the boundary between the grout and the soil. The travel time of the EM waves in the grout was about 5-6ns.

At 500MHz frequency, the dielectric constant of the grout on the fourteenth day was 18. Here we assumed the dielectric constant value of the grout on the twentieth day was about 16.0, then the thickness of the grout was estimated to be around 18.8-22.5cm.

Table 3: Parameters of GPR field tests.

	250 MHz	500 MHz	1 GHz
Antenna space (m)	0.279	0.250	0.076
Step length (m)	0.025	0.020	0.010
Time window (ns)	75	50	24
Number of sample points	188	250	241

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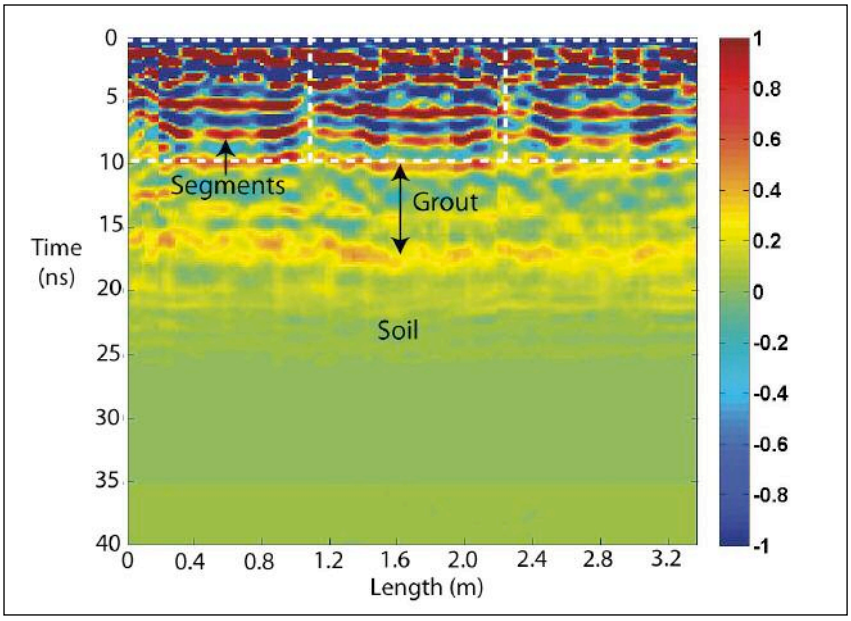
Frequency at 1GHz

The 1GHz GPR detection was carried on 29 December, 2006. The gain due to the increase in frequency and consequently the resolution was offset by the decreasing detecting depth. As a result, the boundary between the grout and the soil cannot be distinguished without ambiguity.

Discussions

As can be seen from the results, the effectiveness of the GPR detection largely depends on the transmitting frequency. Higher frequency tests yield results with a higher resolution. However, as higher frequency waves are attenuated and absorbed faster than the lower frequency waves when propagating, they do not penetrate as far as the lower frequency ones. The degree of attenuation and absorption is governed by the electrical conductivity of the ground. Therefore, the balance between the resolution and the detecting depth determines the choices of GPR frequencies. Among the data of three GPR frequencies 250MHz, 500MHz and 1GHz, used in the field tests, the 250MHz had a low resolution whereas the 1GHz had a shallow detecting depth. As described, the frequency at 500MHz showed the most promising results.



Above: **Fig 6 – Data of 500MHz GPR field test**

Concluding remarks

Several conditions were necessary for GPR to be successfully applied. First of all, the detecting objects (concrete segments, grout and soil) were located in relatively shallow depths, in this case, less than 1m. As a result, relative high frequency GPR with a high resolution can be used. Second, the dielectric parameters of the grout, the soil and the concrete segments were all determined from laboratory and the contrasts among these three materials were sufficiently large. Finally, since the thickness of the lining segments was known as 0.35m, only the boundary between the grout and the soil needed to be found.

In this work, the dielectric constants of the grout and soft silty clay soil at the frequency of 0 - 1.5GHz were first tested using the coaxial probe technique in the laboratory. The results showed that GPR detection should be performed after 14 days in order to have sufficiently large dielectric constant contrast between the grout and the soil.

The dielectric constant of the concrete segments was then determined indirectly by measuring the travel time of the EM waves in the lining segments bounded by a metal plate. The constant can be calculated after the EM wave velocity was known.

Three GPR frequencies 250MHz, 500MHz and 1GHz were used in the field tests carried out in Shanghai Metro line 9. Frequency at 500MHz showed the most promising results. These tests results demonstrated that nondestructive geophysics techniques such as GPR detection can be used to mitigate the risks of long-term ground settlement, a critical issue of shield tunnel construction in soft soil areas such as Shanghai. T&T

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The Ditch Witch 720ML

Fixing what's hard to find

Technical journalist, Ian Clark, takes a look at the world of pipeline network asset management and renovation over the past year

As has always been the case, you cannot fix what you cannot find. For example in the UK alone, there is an estimated 13M kilometers of pipes and cables, so worldwide this figure will be orders of magnitude larger. It is abundantly clear that knowledge of where your services run is vital information both for individual services and in relation to other buried plant. Looking at the records currently available it becomes clear that the growth of our underground infrastructure has to a large extent outstretched the industry's ability to record accurately where each service is buried.

A project called Mapping The Underworld (MTU) has been established to look at this problem. MTU is a partnership between UK research funding bodies, various universities and the private sector aimed at finding a solution to the problem of accurately locating and recording our buried infrastructure.

Rather than simply trying to improve current techniques, MTU is actively developing new, multi-sensor, detection equipment allied to state-of-the-art utility data-basing and visualisation techniques. It aims to address the problem of utility location and recording by bringing together seven leading UK universities in an attempt to combine improved detection, location, integrated mapping and data visualisation into a single integrated, and stakeholder friendly, asset management system.

Whilst the work concentrates on the UK problems, the outcomes should be much more widely applicable. Therefore, the MTU team welcomes contact from relevant organisations across the world. Website: www.mappingtheunderworld.ac.uk

The gear

In terms of equipment availability, the Ditch Witch organisation, an industry leader in the design and manufacture of underground construction equipment, has announced the release of a new electronic locating system, the Ditch Witch 720ML.

Designed for ease of use and engineered to be very sensitive, the 720ML can detect metallic or ferrous objects such as marker stakes, manhole covers, valve boxes, and cast-iron pipe around excavations and horizontal directional drilling sites. The operator has a choice of two audio modes. Four sensitivity settings allow the operator to customise the 720ML to suit soil conditions.

For line mapping work the company has also released the new 250R/T locating system. The 250R/T is said to be one of the most efficient and cost-effective methods for locating and avoiding buried telephone, CATV, power, gas, and water lines. Consisting of a 250T transmitter and 250R receiver, this simple, lightweight system features intuitive controls, an easy-to-read display, and depth estimation up to 4.6m.

The 250T is also claimed to be ten times more powerful than other transmitters in its class. It can apply 33kHz signals via direct connect, induction clamp, or other optional accessories.

Another well-known name in the field of pipeline mapping is Radiodetection. Radiodetection, a world leader in the design, manufacture and supply of underground pipe and cable locators, recently announce the launch of the RD7000 and RD8000 range of pipe and cable locators.

The RD8000 and RD7000 are ergonomically designed, delivering a light weight, energy efficient and exceptionally well balanced tool, which encourages extended use. Both the RD8000 and RD7000 are Centros enabled, which improves the accuracy and repeatability of measurements and delivers unprecedented responsiveness in the field. The RD8000 is the high-end feature model designed for multiple applications and industries. The RD7000 family is for operators who require an application or industry specific locator with a cost effective feature set.

Where electromagnetic field detection is not an option, Radiodetection also offers the new RD1000 Portable GPR System. Using radar technology, the RD1000

Below: **The new Ditch Witch 250R/T locating system**

displays an image map of underground features. With the RD1000, the technician can see a pipe or cable in its topographical context making it ideal for locating and excavating utilities. The advantage over a traditional, electromagnetic locator is that the RD1000 can see nonconductive materials including plastic pipes and can operate in almost any terrain.

In terms of internal inspection, the Pearpoint brand from Radiodetection, has been at the forefront of the industry in the advancement of pipeline inspection technology. Pearpoint recently continued this tradition with release of the P350 flexitrax portable crawler system. With flexitrax, Pearpoint gives inspection professionals worldwide a robust and highly portable digital video crawler system that suits any environment.

The P350 flexitrax system supports three interchangeable, high-resolution cameras. Each camera features the latest generation, ultra-bright white LEDs that ensure a clear picture and a long, maintenance-free life. The P350 flexitrax command module allows operators to zoom and rotate photos and live or recorded digital video in real-time. The command module also introduces Mimic™ display, an intuitive way of controlling pan and tilt. The P350 flexitrax is engineered to operate in almost any environment.

Cleaning systems have also seen movement in their technology over the past year with the introduction of a new specialised water main cleaning unit by Fastflow Pipeline Services Ltd of the UK. The new Trunk Main Cleaning equipment differs significantly from systems currently on the market. In terms of water usage, the new system utilises as little as 10% of the water volume required by most existing systems. This in turn means that the impact of the used water on the environment is greatly reduced and also eliminates the need for major settling lagoon structures on site which are commonly associated with traditional pigging techniques.

The 'patent applied for' modular design enables the cleaning system to be quickly and easily adapted to operate effectively in pipe diameters from 380mm up to 1,250mm. The spray head is equipped with a unique centralising system, ensuring the spray head rotates along the central pipe axis regardless of any changes in pipe diameter. The spray head is equipped with a variable number of high pressure/low volume spray nozzles, the number of which is varied according the nature of the pipe being cleaned and the extent and type of debris to be removed.

On the wastewater side, Infotec Consulting has introduced FLUSHER. FLUSHER is an innovative and unique drain and sewer cleaning system, which utilises the potential energy that can be created within the sewer to clean itself and the surrounding catchment area. The system can be demounted and moved to different locations, enabling it to be used as an effective maintenance tool. An environmentally-friendly solution, the new device is, according to the manufacturer, set to revolutionise the UK's sewer and drainage, cleaning and maintenance industry.

FLUSHER is a gate device that, once installed, starts initially in a closed position, causing effluent flows to accumulate on the upstream side of the gate. When the flow reaches a set level, the gate opens fully, releasing the contained effluent to surge through the sewer in high volume and at a high flow rate, so scouring fats, silt, or other built up material from the sewer walls and out of the invert.

The process is continually repeated so allowing any materials or deposits left behind by one cleaning action to be removed by the next. Because the flow level varies, deposit build ups are dramatically reduced throughout the sewer. Not only does the cleaning action occur downstream, but also upstream as the flows generated are active on either side of the gate. The flows also act on laterals as they surcharge connections during the active cleaning operation. Designed to be installed at a manhole chamber the gate device does not completely seal the sewer bore and so allows surcharge flows to circulate around it without obstruction.

Lining systems

In last year's review we looked at the development of Steam cure and UV cure linings as new technology both of which tend to utilise air inversion techniques to initially position the liner. The use of inversion drums for this work has to some extent limited the pipe sizes suitable to such systems.

To overcome these limitations Insituform Technologies Inc has developed an Air Inversion system with the capacity to invert liner up to 2,000mm diameter with the need of a drum. The new system, known as the Dual Gland Air Inversion (DGIA) unit allows air inversion over lengths in excess of 300m in a single operation.

The new system takes factory impregnated liner directly off the delivery truck on site, eliminating any need to confine

Below left: **Fastflow Pipeline Services Ltd in action** Below right: **The ITI Dual Gland Air Inversion (DGIA) system**

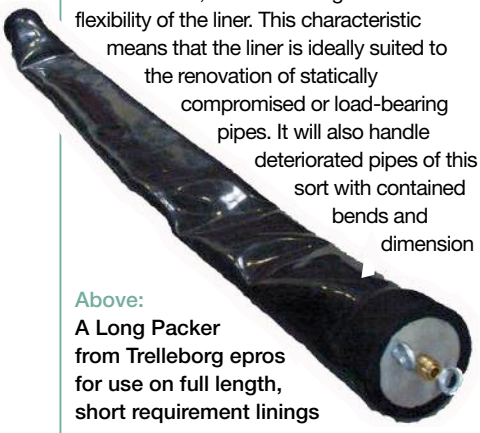
it in any way. The inversion process involves attaching the free end of the liner sock to the DGIA unit 'gland'. The liner is inverted through the 'gland', which is designed to allow air pressure to be applied inside the inverting liner on the inside of the gland, whilst allowing the remainder of the liner to remain in 'free air' using a specially designed sealing arrangement. The 'gland' maintains the internal pressure required for inversion to proceed whilst allowing the free movement of the liner through the 'gland' during the inversion process.

KOB, the German lining manufacturer renowned for the Brawoliner system recently launched two new liner types BRAWOLINER 3D and BRAWOLINER XT to address specific problems often encountered in sewer rehabilitation projects, particularly lateral connection pipes and service drains with in-built changes in diameter and structural insufficiencies.

There has for some time been a need for a liner system that can accommodate diameter fluctuations during the installation process without the need to excavate to access the diameter change location or design a liner with the diameter change in the 'right position' before installation. BRAWOLINER 3D is specifically designed to address this circumstance where, for example, a pipe varies in diameter from DN100 to DN150. This can now be lined in a single pass with one liner giving a crease free finish to the cured liner. BRAWOLINER 3D is available in the nominal diameters from DN75 to DN100 and DN100 to DN150 and is available in lengths of 25m, 50m, or 100m. Soon to be launched will be the DN 150 to DN 225 system.

Longitudinal cracks and broken fragments can decrease the static performance of pipes dramatically. The rehabilitation of this type of damage is essential to restore strength to the fabric of the pipe and maintain the required design stability.

The new BRAWOLINER XT system is designed to achieve a significantly higher stiffness than other liner systems available on the market, whilst retaining the inherent flexibility of the liner. This characteristic means that the liner is ideally suited to the renovation of statically compromised or load-bearing pipes. It will also handle deteriorated pipes of this sort with contained bends and dimension changes. BRAWOLINER XT is available in nominal DN150 and DN 200 diameters and is available in lengths of 25m, 50m, or 100m.



Above: **A Long Packer from Trelleborg epros for use on full length, short requirement linings**

Above: **Applying the ombran manhole rehabilitation system inside a manhole**

There has also been development in the lining sector using equipment previously thought to be limited to the localised repair or 'Patch' market. Trelleborg epros has noted that whilst contractors have often utilised short-length, patch repair technology, more recently, they have also taken to utilising this technology to complete 'full length' repairs in straight pipes that are simply short in length. This is because the system enables renovation to be completed without the need to mobilise a full size manhole to manhole lining rig and its support equipment. To meet this growing demand, Trelleborg epros recently announced the expansion of its inflatable packer range to include units that have the capacity for this type of work.

The new packers come in lengths up to 5m and are applicable to pipe diameters from 100mm to 600mm. The materials and resin used with the system provide a fast installation whilst producing a fully structural rehabilitation. The system has been in use across Germany for some time where it proved to be highly successful in completing such short-length repairs.

Trelleborg epros also recently launched an economical, high-quality rehabilitation solution called epros SprayCoating. The two coating systems available include EproCoat SB and EproCoat SBA (antistatic) both of which have obtained the technical approval by the German institute for Construction Engineering (DIBt) as organic protective coating for concrete surfaces. Both coating systems are polyurea-based ambient-cure two-component coatings. SprayCoating with EproCoat SB and EproCoat SBA (antistatic) is well-suited to the repair of manholes, settlement tanks, separating systems, concrete structures, man-entry pipe systems, tunnels and steel structures. The antistatic EProCoat SBA is used for preventing ignition hazards from electrostatic charges in potentially explosive locations, eg. in petrochemical refineries, wash and cleaning stations, oil pipelines, tank pits, containment structures and marine offshore platforms.

MC Chemical has also been developing a new manhole rehabilitation system known as 'ombran'. The ombran system comprises a number of different materials each with a particular property which offers a solution to a particular problem. The products work across of range of chemical conditions from the acidic to the highly alkaline. They offer properties for the long-term waterproofing of the structure, an ability to re-profile the structure and to adjust and strengthen the construction of the manhole frame itself.

A typical standard installation comprises some four applications. After full cleaning of the old manhole surface has been achieved an initial bond coat, typically ombran HB, is applied to ensure any further coatings hold firm. The re-profiling coat, typically ombran R or ombran MHP, is then applied to reshape the manhole structure to that required for efficient operation. A further bond coat is then applied to ensure that the top sealing coat, typically ombran ASP or ombran MHP, has a solid hold fully sealing the structure for decades to come.

Whilst this is a typical solution for the average defective manhole, the ombran system is also very flexible and MC's engineers and representatives can advise on and adapt the installation to suit almost any circumstances that might be encountered in a deteriorated manhole.

So once again it seems that there is still more to come by way of innovation within the pipeline renovation industry. T&T

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Global solutions for rehabilitation

Ian Clarke delves into the world of pipeline rehabilitation and reports from two projects where new technologies are proving their worth

Above: **A typical site set up on the Palos Hills rehabilitation project**

Pipeline rehabilitation solutions have become increasingly popular options across the world over the past two decades as an alternative to open cut or new bored installations. This is due to the minimal impact offered by such solutions on the local social structure, environment and economy because of the low levels of disruption achievable using such techniques.

One of the leading companies in the global pipeline rehabilitation field is Insituform Technologies Inc (ITI), which offers a variety of pipe lining solutions for both wastewater and potable networks.

In the wastewater sector ITI offers its world-renowned Insituform CIPP system for gravity sewers and culverts as well as varieties of standard and composite liners for pressure pipe/rising main systems and other industrial applications.

The company recently launched its Insituform Blue division, which is dedicated to the clean/potable water pipeline network sector of the industry. This operation offers the PuraGuard system, a close-fit pressure pipe rehabilitation system which includes PolyFlex and PolyFold renewal systems, the Thermopipe water main lining system and the iTAP service pipe connection system.

ITI not only manufactures its own CIPP liner products but also undertakes the installation contracts, which it claims enables it to provide the closest possible quality control of its liners from the start of liner manufacture to handing back a completed lining contract to the client and all stages in between.

Wastewater solutions - Palos Hills

The Palos Hills Sanitary Sewer Lining Project is typical of the sort of project that is undertaken by ITI in the dirty water sector. However, whilst this is a project that runs over more than a year, ITI's lining capability has been applied to pipe rehabilitation work from just a few meters to multiple linings over several kilometres in a single project.

The Palos Hills project was initiated by the client, the City of Palos Hills in Illinois, USA primarily to address the problem of inflow and infiltration (I&I) at various locations across its sewer network. The City engaged Christopher B Burke Engineering Ltd. as the project's consulting engineer to design an effective solution to the problem.

After careful consideration of the options available, it was decided to utilise a trenchless solution in the form of CIPP lining to rehabilitate the pipe, seal the network and prevent future I&I problems whilst providing a provides a long term, low cost, structural solution.

Insituform Technologies USA Inc, a subsidiary of ITI, was awarded the contract to complete the required work. This included the use of CIPP rehabilitation technology to line some 48.8km of 200-685mm diameter pipe at various locations across the City.

CIPP

The Insituform CIPP process is designed for sewer repair and can be used to rehabilitate sanitary sewers, storm sewers and force mains. It is comprised of a resin impregnated needle felt liner material that can be inserted into the host pipe using a number of different techniques. The liner provides a jointless, seamless, pipe-within-a-pipe with the capability to rehabilitate pipes ranging in diameter from 150-2,450mm diameter and to negotiate bends.

The system can significantly reduce infiltration and eliminate leakage from a system as well as negate the intrusion of roots into a lined pipe. The system also helps clients avoid large capital costs of expanding treatment facilities and the

environmental problems caused by sewer overflows by improving flow characteristics and restoring structural integrity to damaged sewer pipes with a 100-year design life.

The Insituform CIPP process also offers flexibility in both the method of installation and the cure process as it can be inverted with either air or water, or pulled into place and cured using either steam or hot water. All processes are consistent with nationally recognised standards and ITI's own ISO-certified quality control programme.

Liner installation

Obtaining access to residential properties for much of the installation work (particularly at the smaller diameters) to gain manhole access for the liner installations was amongst the main challenges encountered on the Palos Hills project.

Typically a liner installation required this access to be achieved. This required that all residents and local businesses affected by the lining operation were informed 24 hours before the start of the lining process. If, due to weather conditions or other operational obstacles, the work was not undertaken at the proposed time, another notice would be delivered explaining the revised schedule.

Prior to installing the CIPP liner, the pipe being lined is thoroughly cleaned, CCTV'd to ensure that there are no obstructions that would adversely affect the lining installation and analysed to ensure that the position of lateral connections that may need reopening after the lining operation are known and located.

Where water inversion is used, normally a tower is constructed over the access manhole, or access pit where no manhole is available, to give the necessary head of water pressure to achieve the liner inversion into the host pipe. Where a tower construction is impractical ITI's CHIP inversion system is utilised where water pressure for the inversion process is applied through a pressurised containment unit.

The liner is inverted into position and the cure process started with circulation of the liner water through a boiler to bring it to the temperature required to initiate the resin cure. Once the pre-determined time at the cure temperature has elapsed the water is removed from the liner leaving it in place inside the host pipe. The liner ends are sealed and any lateral connections are then reopened. A further CCTV survey is undertaken to ensure that the liner is installed to the required standard and to provide the client with a record of the installation at the end of the work.

The Palos Hills project started in May, 2008 and is expected to be completed by August, 2009. The contract including engineering, point repairs and flow monitoring to certify the results is valued at US$5.8M.

According to Dave Weakley, Commissioner Public Works, City of Palos Hills: "Because the City decided to forgo the pre-televised inspection phase of the project prior to bidding the project, and because the City was committed to completing all point repairs in-house, allowing more dollars to be invested in lining work, we needed to develop great communication between the contractor and the City. To this end, information collected from the cleaning/pre-lining inspection phase of the project had to be reviewed in a timely manner. The experience of the lining contractor has proven to be invaluable. Using several external computer hard drives, which we exchanged on a weekly basis, the contractor has been able to collect inspection data, pinpoint problem areas and deliver the digital information to the City for staff review. This process has allowed the City adequate time to complete point repair work without delaying the lining contractor."

Weakley went on to say: "The project has presented several unique repair opportunities that have required the contractor and City to think outside the box. Having an experienced lining contractor with creative competent personnel partnering with the City has proven to be a winning combination."

Kevin Coburn, Business Development Manager for ITI, said, "ITI's CIPP system is well-suited to the circumstances we find on the Palos Hills project and was the process chosen for this important project due to its effectiveness when it comes to eliminating I&I. It also provides a long term, low cost, structural solution for the client. In short, our CIPP liners provide a value driven and effective solution."

GRP culvert rehabilitation

On a different type of rehabilitation project in the UK, Insituform Technologies Ltd (ITL) recently utilised its GRP (glass reinforced plastic) lining expertise to renovate 950m of deteriorated main drainage culvert, as well as 13 manholes, at the Crossness Sewage Treatment Works (STW) in Abbey Wood,

Right: **Inserting the CIPP liner into the host pipe in this instance using a CHIP unit**

Below: **Confined space precautions were utilised throughout the Crossness lining operation**

Above: **The main drainage culvert condition prior to the GRP lining operation**

London, UK, at a project value of US$2.7M.

Known as the 844G MDC (Main Drainage Culvert) Rehabilitation Project, the ultimate client for the work was Thames Water, which has responsibility for the efficient functioning of the STW. Design consultant for the project was Hyder plc and the main contractor for the work was Laing O'Rourke. ITL was subcontracted to complete the GRP lining installation along with some chemically resistant coating applications in both the lining and the manholes.

The problem

The MDC in need of renovation was a reinforced concrete structure running beneath the STW. There would be no impact from the project on the general public or local traffic as all works were within the confines of the treatment plant.

Over the years the concrete fabric of the culvert had suffered attack from hydrogen sulphide and sulphuric acid, causing structural deterioration. The purpose of the lining project was to rehabilitate the culvert with a structural GRP liner, along with the 13 manholes providing access to it. The combination of GRP and chemical resistant coatings would prevent further degradation and restore the culvert's life expectancy to in excess of 50 years.

Solution

After careful consideration of the options available for the renovation of the culvert, it was decided that GRP lining offered the most effective solution, mainly due to the fact that the cross section of the culvert changed considerably over the 950m length which was in need of repair. Following the renovation, part of the length now comprises a circular 1,400mm diameter profile, part comprises a 945mm x 1,400mm D-shaped profile and the remainder comprises a 2,000mm x 1,400mm ovoid profile. As GRP sections are effectively 'made-to-order' this offered the client an excellent solution to the culvert renovation problem on each of the different profile sections.

Below: **The completed GRP liner with lateral connections reinstated**

With GRP liners providing a structural solution with a high degree of chemical resistance, this was also seen as the long-term solution to the chemical attack problems which caused the deterioration in the first place.

The profile sizes and shapes also enabled ITL to use man-entry techniques for the installation of the liners with access mainly via the existing manholes serving the culvert. However, one segmental shaft had to be sunk at one point to maintain effective and safe access on one of the longer manhole-to-manhole lengths.

As usual with GRP installations, the liner segments, manufactured by Stanton Bonna Concrete Ltd in 1.2m long sections, were transported from the access manhole to the lining position on trolleys. They were then carefully positioned by hand using the location socket joints built into the liner ends and supported around the perimeter against the inner wall of the host culvert, thereby requiring no specialist equipment to achieve the installation. Once correctly positioned, the annulus between the host culvert and the liner was filled using a cementitious grout. The joints between the liner sections were sealed prior to grouting with an epoxy based mortar which, once set, was further coated with a chemically resistant coating.

Installation

The lining project commenced on 15 October 2007 and was completed in August 2008.

Commenting on the project for ITL, Dave Rees, Project Engineer, said: "The use of GRP liners to overcome the chemical deterioration of the culvert was an ideal solution. ITL has the experience and expertise to complete this sort of project to a very high standard, ensuring a significant long-term increase in life expectancy for the culvert in question. Once this work is finished, the STW at Crossness will be able to rely on the effective operation of this culvert for many decades to come."

For Thames Water, Ian Laber, Construction Team Manager, said: "Given the variety of sizes and shapes involved along the length of the culvert, we had to select a rehabilitation technique that would not only enable us to solve and eliminate as far as possible the culvert deterioration problem now, but also one that would prevent further attack in the future, whilst at the same time providing a structurally sound pipe over the long term at minimum loss of capacity. The GRP solution gave us this in an acceptable time frame and budget." T&T

Classified

RECRUITMENT

Get Your Career On The Move

Are you looking for a career where you can make a difference? As a MTR Corporation team member, you can.

The MTR Corporation has established itself as one of the world's leading railways for safety, reliability, customer service and cost efficiency. We have expanded our business from beyond the construction and operations of a mass transit railway system. We have prided ourselves in growing the communities and enhancing the quality of life of Hong Kong people. Today, MTR Corporation is a diversified company with interests in transportation, property management, many other commercial activities, investment projects and consultancy services worldwide.

We would like to invite applications for the following positions in our Projects Division for the construction of new railway extension projects:

Construction Manager-Civil **(Ref: J08078)**

Reporting to the Project Manager, you will be responsible for delivering the assigned project safely, on time, within budget and in compliance with all statutory requirements and specifications.

You will provide construction inputs to the preliminary design and tender documentation preparation, evaluate the technical aspects of tender submissions and recommend tender award. As Engineer's Representative during the construction phase, you will lead a team of resident site staff to manage the assigned Works Contracts, including but not limited to detailed design, use of appropriate methods of construction, safety, environmental, quality, programming, land and commercial aspects.

You should be a Chartered Engineer with a degree in Civil Engineering or equivalent and have at least 16 years' relevant experience in the design and construction of major civil construction projects, with at least 4 years at senior management level. Direct and extensive involvement in heavy tunnelling works is a definite advantage.

Senior Construction Engineer-Tunnels **(Ref: J08143)**

Reporting to the Construction Manager, you will be responsible for delivering the project safely, on time, within budget and achieving completion in compliance with all statutory requirements and specifications. You will lead a team of resident site staff to manage the assigned works contract during the construction phase, including, but not limited to the construction, safety, environmental, quality, programming, land and commercial aspects.

You should be a Chartered Civil or Mining Engineer with at least 12 years' soft ground tunnelling experience, including compressed air tunnelling, EPBM, slurry TBM and hand tunnelling techniques, preferably with at least 6 years at management level.

Applications

You are invited to apply online at ***http://www.mtr.com.hk/careers*** or send in your application either by email to ***recruit@mtr.com.hk*** or by ***mail*** to the following address on or before **31 October 2008:**

Human Resource Management Department
MTR Corporation
G.P.O Box 9916
Hong Kong

All information provided by applicants will be treated in strict confidence and used for recruitment purposes only.
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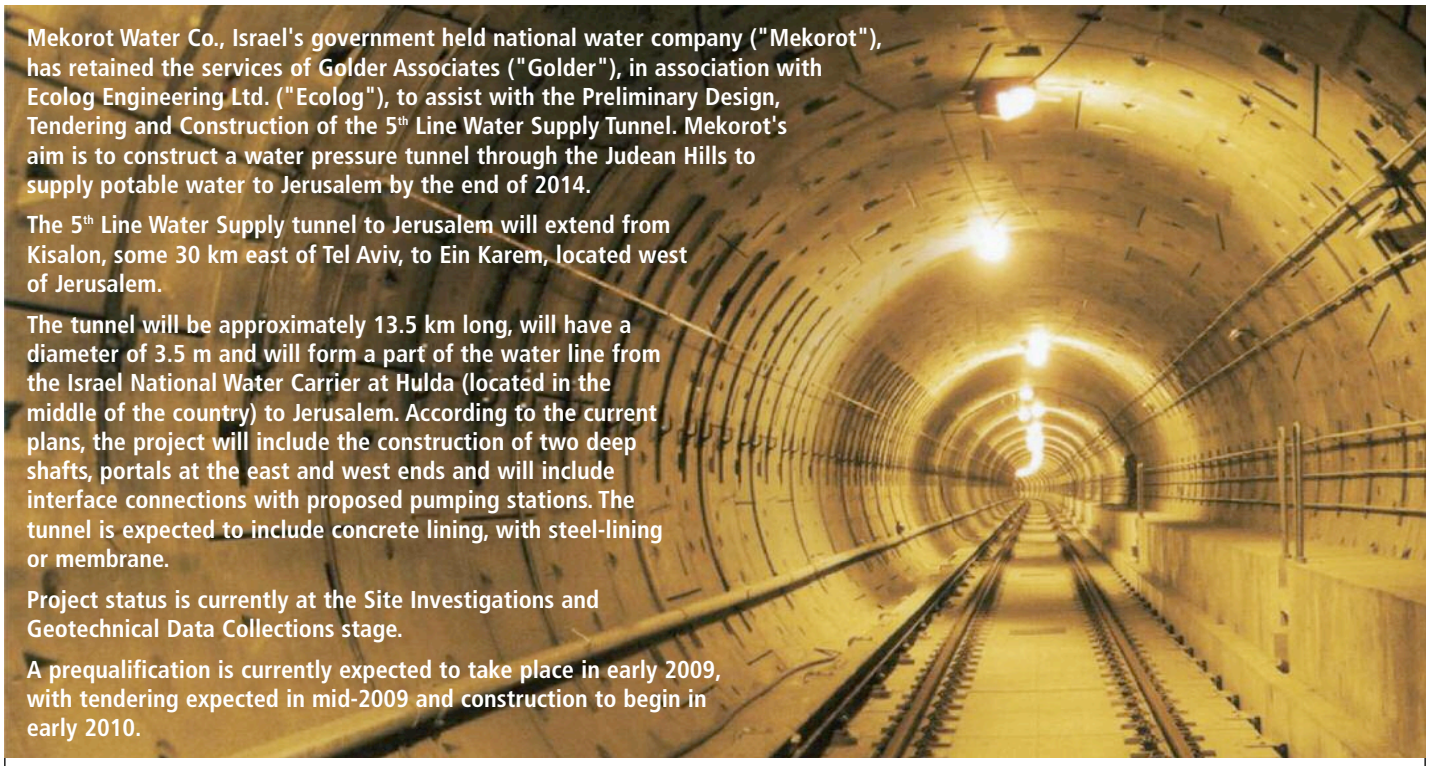
MTR

PREQUALIFICATION ANNOUNCEMENT



Mekorot Water Co., Israel's government held national water company ("Mekorot"), has retained the services of Golder Associates ("Golder"), in association with Ecolog Engineering Ltd. ("Ecolog"), to assist with the Preliminary Design, Tendering and Construction of the 5th Line Water Supply Tunnel. Mekorot's aim is to construct a water pressure tunnel through the Judean Hills to supply potable water to Jerusalem by the end of 2014.

The 5th Line Water Supply tunnel to Jerusalem will extend from Kisalon, some 30 km east of Tel Aviv, to Ein Karem, located west of Jerusalem.

The tunnel will be approximately 13.5 km long, will have a diameter of 3.5 m and will form a part of the water line from the Israel National Water Carrier at Hulda (located in the middle of the country) to Jerusalem. According to the current plans, the project will include the construction of two deep shafts, portals at the east and west ends and will include interface connections with proposed pumping stations. The tunnel is expected to include concrete lining, with steel-lining or membrane.

Project status is currently at the Site Investigations and Geotechnical Data Collections stage.

A prequalification is currently expected to take place in early 2009, with tendering expected in mid-2009 and construction to begin in early 2010.

Mekorot has distributed a questionnaire to potential contractors for collecting relevant information with respect to potential participants in the project. **For more information**, please contact Darcy Cowan, Golder-Ecolog Project Manager, at **+1 905-567-4444** or via e-mail at **dcowan@golder.com.**

MEKOROT ISRAEL NATIONAL WATER CO. | Golder Associates | ECOLOG ENGINEERING LTD אקולוג הנדסה בע"מ

EQUIPMENT FOR SALE

MURPHY

J Murphy & Sons are selling the following Tunnelling Equipment:

- Curved steel sleepers (approx. 3,000) to suit S24 rail – 4.150m tunnel diameter, 10T axle load.
- Symmetrical turnouts 610mm (6No.) single to double track 1500mm centres to suit S24 rail.
- Muhlhauser 12.5m³ hydraulic dump cars air braked on one axle, with automatic coupling and side tipping (6No).
- Muhlhauser Hydraulic dump station (1 No.).
- FB50 Flat bottom Siltbuster (1 No.).
- CP2000T Paddle assisted colloidal grout mixer (1 No.).
- Cable 30 x 2 x 1/0.6 Pvc SWA Pvc ESI (9,000m).
- Fire extinguishers CO2 (2kg & 5kg) and Dry powder (2kg & 5kg).
- Quantity of TBM – RME131SE Series 11500 spare parts.
- Quantity of TBM – RMP131SE Series 19900 spare parts.

For further information please contact:

Geoff Willetts – Project Director +44 (0) 7767 437 614
Sean Martin – Mechanical Engineer +44(0) 7778 747 095

Do you have a vacancy to fill or some equipment to sell?

Call: Gary on +44 (0) 208 269 7849
Email: gtween@tunnelsonline.info
Fax: +44 (0) 208 269 7840

STOCK REDUNDANT TO NEEDS

at Cessation of works City West Cable Tunnel Sydney Australia - Cleaned and Placed on local Transport

(The machine is being buried, therefore Cutter Head, Forward Shell, Stationary Shell and Tailshield not available for sale)

TBM

Manufacture Details Lovat RMP 147SE series 22201 Rock Single Shield TBM Built 2005

Driveage to Date Algeria 4 Kilometres medium rock, Sydney 1.5 kilometres medium rock.

Dimensions 3.7metre cut, 3.6metre Outside Diameter, 3.2 inside Inside Diameter Trapeziodal 6 piece segmental lining.

Details Bi Directional Hydraulic Cutter Head, 27 x 15.5 inch cutters CTS brand 27 x Palmieri brand + spare rings and bearings, 610mm Belt Conveyor x 41 metres dual drive, Arm style Erector 180 degree rotation, 12 x 115 tonne push cylinders 1725 stroke, Set up for Pea Gravel backfill Aliva 252 Electric Pump Compair 225cfm compressors x 2 off, CFT HTSM 1/150-42 Dust Filter and Korfmann fans, Probe Drill Boart Longyear HD 150.

ROLLING STOCK

Mining Equipment 750 mm guage 1 metre segment cars 2 x pairs, Mining Equipment 12 man capacity manrider x 4 off Probe drill flatcar 2.5 metres x 1 off.

SEGMENT MOULDS

CBE Group Built 2006 14 sets of moulds, 6 pieces Tapered Trapezoidal cast 9400 pieces total. Horizontal Dowels and Vertical Straight Spear bolt to connect. Single Rubber Gasket. Wheels to suit Carousel.

Dimensions: 3600mm outside Diameter x 3200mm inside diameter x 1000mm long plates tapered 12 mm.

Accessories: Vacuum Lifter x 1 off, 3 piece and 6 piece manual handlers and Calibration Equipment.

THIESS TUNNELLING

Contact
Martin Bell, Plant Operations Superintendant
THIESS TUNNELLING
Tel: 02 93329524 **Fax**: 02 93329554
Mobile: 0439 439593 **Email**: mbell@thiess.com.au

WEBSITE DIRECTORY

Dates & Events

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

27-28 OCTOBER
20th National Conference, Tunnelling Technology & The Environment Niagara, Ontario, Canada
Organised by TAC, the Tunnelling Association of Canada, this year's conference focuses on Tunnelling Technology and The Environment. Contact: +1 604 629 1736; email: info@tunnelcanada.ca; web: www.tunnelcanada.ca

29-31 OCTOBER
Railroad Crossings Through the Central Pyrenees Zaragoza, Spain
This is the first International Conference on rail crossings through the Pyrenees organised by the Colegio de Ingenieros Canales y Puertos. Contact: Proyectos y Personas, eventos SL: Tel: +34 976 3911 282; Email: info(at)proyectosypersonas.com; web: www.proyectosypersonas.com

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

10-13 NOVEMBER
CityBuild, 5th Underground City 2008, Moscow, Russia
An annual event to demonstrate experience in the development of the underground space for the creation of city infrastructure and increase the attractiveness of investing in multipurpose underground structures. Contact: Tel: +7 (495)9802186; email: irb@global-expo.ru; web: www.city-build.ru

16 DECEMBER
Study Day on Geological Drillings Brussels, Belgium
This one day seminar on geological drilling will take place at the Tractebel Forum in Brussels. Contact: ABTUS-BVOTS, Tractebel Forum, 7 Avenue Arianelaa, 1200 Bruxelles, Belgium; Tel: +32 02 770 9095; email: wdl.abtusbvots@telenet.be

15-16 JANUARY 2009
Shotcrete 2009 Tyrol, Austria
Wolfgang Kusterle, Professor of Building Materials at the University of Applied Sciences, Regensburg, heads up this German-language conference. Contact: Agneta Kusterle, Sekretariat; Tel: +43 (0) 650 8244610; email: spritzbeton.kusterle@aon.at; web: http://members.aon.at/kusterle/

MAY 2009
Tunnels & Underground Spaces for Transportation & Urban Development Tehran, Iran
The 8th Iranian conference on tunnelling and underground spaces is designed to act as a platform for national and international companies to demonstrate their capabilities, in view of the large number of tunnelling projects being planned in this country. Contact: Iranian Tunneling Association; Tel: 98 21 8863 0495; email: info@irta.ir; web: www.irta.ir

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

14-17 JUNE
RETC 2009 Las Vegas, Nevada, USA
RETC is recognised as a leading international tunnelling event for contractors and engineers. Last year, conference attendance exceeded 1500 professionals from more than 30 countries and the exhibition sold out in record time. With a venue of Las Vegas, 2009 is sure to be even more of a success. Contact: SME; web: www.retc.org

22-25 JUNE
5th Symposium of Strait Crossings Trondheim, Norway
Organised by SINTEF and the Norwegian University of Science and Technology, this major symposium aims to act as a forum for the exchange of information, research, new technology and recent experience. The event will also include an exhibition. Contact: NTNU; email: sc09@adm.ntnu.no; web: www.straitcrossings.com

09-11 SEPTEMBER
IBTTA 77th Annual Meeting Chicago, USA
The International Bridge, Tunnel and Turnpike Association's (IBTTA) 77th Annual Meeting and Exhibition will bring together more than 1000 toll agency professionals for 3 days of networking and innovations in toll industry. Contact: IBTTA: Tel: +1 202 659 4620; web: www.ibtta.org

13-16 SEPTEMBER
EURO:TUN 2009 Bochum, Germany
The 2nd International Conference on Computational Methods in Tunnelling. Organised by the Institute for Structural Mechanics. Contact: Conference Secretariat: Tel: +49 234 32 29051; web: www.eurotun.rub.de

02-04 MARCH 2010
International Conference on Tunnelling, Kuala Lumpar, Malaysia
Organised by IEM - Tunnelling and Underground Space Division, The Institute of Engineers Malaysia. Contact: Tel: +60 3 79 68 40 01; web: www.iem.org.my/ external/ tunnel/index.htm

BRITISH TUNNELLING SOCIETY

12 NOVEMBER: **2nd Avenue Subway**
Joint meeting with BGA on the Geotechnical Design and Construction of New York's mega project. 5.30pm for 6pm, at the ICE, Westminster, London.

11 DECEMBER: **Debate - Speakers TBC**
5.30pm for 6pm, at the ICE, Westminster, London.

15 JANUARY: **Canada Line Transit Tunnels**
Members of the project team discuss EPBM excavation for Vancouver's latest metro line. Presented by Prof Kovari/Prof Dan Eisenstein, Jeff Hewitt, Remo Grandori, Marco Maccichino.

17-19 MARCH
ISTSS 2010 Frankfurt, Germany
The 4th International Symposium on Tunnel Safety and Security. Manuscript abstracts should be submitted to the Secretariat by 01 June 2009, poster abstracts by the 01 October 2009. Contact: Anders Lönnermark, SP Technical Research Insitute of Sweden; tel: +46 10 516 56 91; email: anders.lonnermark@sp.se; web: http://www.sp.se/en/units/fire/news/ISTSS2010/

14-20 MAY
2010 ITA World Tunnel Congress, Vancouver, Canada
Prior to the 2010 Winter Olympics, ITA visits Vancouver, British Columbia, for its yearly conference and exhibition. Contact: web: www.wtc2010.org

18-20 MAY
InterTunnel 2010 Turin, Italy
Tunnelling exhibition aimed at companies and suppliers involved in building and equipping tunnels and firms providing the systems and expertise for their safe and efficient operation. Contact: Mack Brooks Exhibitions; web: www.intertunnel.com

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Tris Thomas, 'Tunnels & Tunnelling International', Progressive House, 2 Maidstone Road, Sidcup, Kent DA14 5HZ, United Kingdom.
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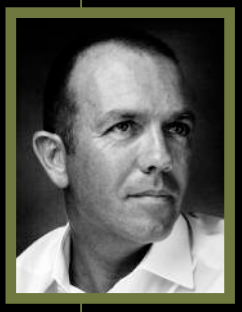

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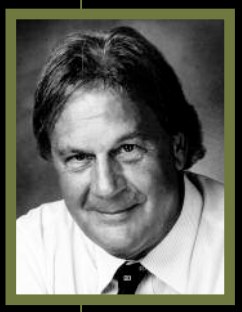

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