SEPTEMBER 2009

tunnels & tunnelling INTERNATIONAL

FOCUS ON IMMERSED TUBES

T&TI visits Limerick's immersed tube and studies fire cracking in concrete

TRENCHLESS TECHNOLOGY

A report on the importance of keeping on top of asset deterioration

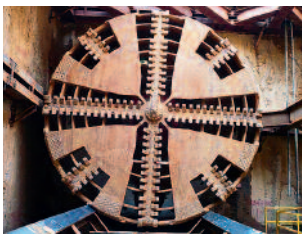
HIGH PRESSURE IN DELHI: GO FOR GOLD.

DELHI | INDIA

PROJECT DATA	CONTRACTORS
Delhi Metro Phase II, 10x EPB Shield Diameter: 6,460mm-6,640mm Cutterhead power: 6x 630kW, 2x 640kW, 2x 1,600kW Tunnel length: total of 23,116m Geology: silt, sand, rock	S-403, S-404: Metro Tunnelling Group JV (Dywidag International GmbH, Larsen & Toubro Ltd., Samsung Corporation, Ircon International Ltd., Shimizu Corporation) S-411, S-412: CEC - Soma JV (Continental Engineering Corporation, Soma Enterprise Ltd.) S-445, S-446, S-447, S-448: ITD - ITD Cem JV (Italian-Thai Development Public Co. Ltd, Italian-Thai Development Cementation India Ltd.) S-495, S-496: Alpine - Samsung – HCC JV (Alpine Mayreder Bau GmbH, Samsung Corporation, Hindustan Construction Co. Ltd.)

The Indian metropolis Delhi is preparing itself for the 19th Commonwealth Games in the coming year. The organizers expect 5.5 million visitors. In order to guarantee the mobility of both visitors and the 16 million inhabitants, the urban subway network is being extended. Over 30 kilometers of the total 120 kilometers of "Metro Phase II" are being constructed using mechanized tunnelling. The complete operation will take a mere three and a half years.

The client, the Delhi Metro Rail Corporation (DMRC), opted for Herrenknecht tunnelling technology for a large number of the sections. Ten Earth Pressure Balance Shields (Ø 6,460mm – 6,640mm) are excavating a total of 23.1 kilometers of tunnel under great time pressure, achieving top performances of up to 37.5 meters a day. Five of the machines were already able to complete their partial section on schedule, offering a foretaste of the record performances to be shown by the athletes at the Commonwealth Games in October 2010.



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An immersed tube element is floated out into the River Shannon in preparation for sinking on Limerick's 675m Immersed Tube Tunnel project in Ireland (p15).

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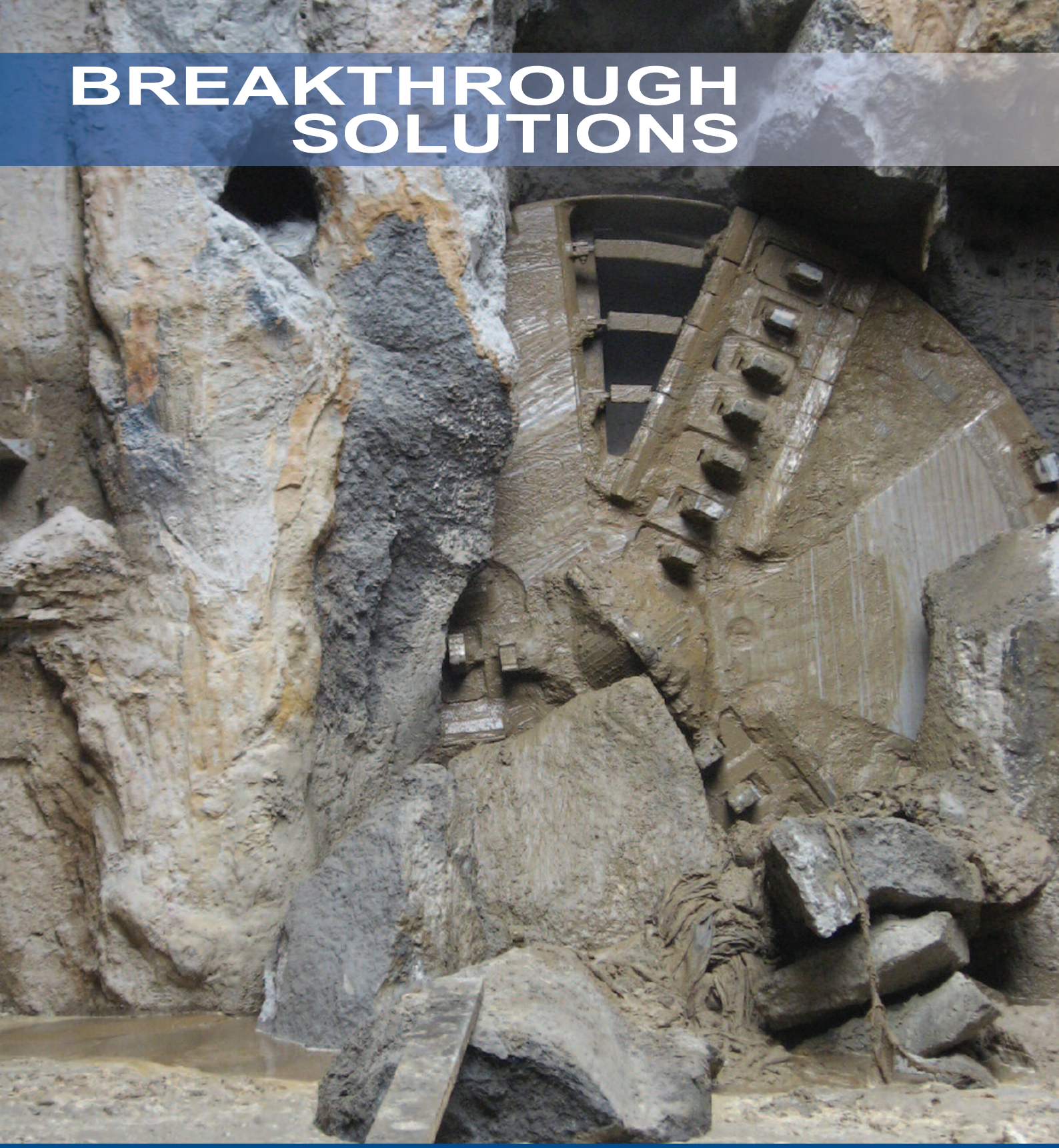
BREAKTHROUGH SOLUTIONS



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In the right hands

Somebody recently asked me if I though NATM was dangerous. That's similar in many ways to asking me if I think cars are dangerous. And the only answer I can give is – it depends who's driving them.

A 'car' is an inanimate object designed by humans to get somewhere. It's only when somebody jumps in, turns the key and stamps on the gas that an automobile ranges from being a safe method of transport to a potential deathtrap.

First up, lets just remove from our NATM/car comparison the completely irresponsible driver who flouts the rules of the road, drinks and drives, speeds for the fun of it etc. These people are serious incidents – NOT accidents, waiting to happen. To clarify, an accident implies a lack of blame, which is clearly not the case in this instance. I don't believe anybody this 'irresponsible' would last two minutes in the tunnelling industry, so the comparison simply isn't relevant.

Ok, with them gone, the parallels between cars and NATM, and in fact tunnel construction methods generally, are actually pretty clear. It's about the user understanding the risks associated with their journey, and the conditions they are taking that journey in.

Consider two scenarios: Firstly, a motorway journey on a clear day with no serious time constraints. If you were to drive at the speed limit, taking the usual care and attention, the chances are very good that you'll arrive at your destination safely (on time and on budget!).

Now, let's throw a unexpectedly busy icy road with poor visibility into the mix, and to make matters worse the driver is late and really needs to make up time. The less risk aware may simply choose to push on, drive quicker and cut the odd corner, and in such icy conditions exponentially increase their chances of having a serious crash. The sensible thing would be to re-assess the situation, and therefore the risk, and deal with it accordingly. Far better to get there in one piece.

Similarly, if you push NATM irresponsibly hard and fast in unexpected, troublesome ground it could be an accident waiting to happen, and if that accident happens it can have extremely severe consequences. Again, a re-assessment of the conditions, method, speed of advance and risk allocation is the only sensible option.

These are all human decisions.

NATM is very flexible, it can be changed swiftly to deal with the unexpected. Actually instigating such changes though, is all down to the people practicing the method. Accidents aren't the fault of NATM, but the fault of its poor application.

So I would say that NATM, like a car, is only ever as safe, or dangerous, as those that use it.

Tris Thomas

COMPANIES IN THIS ISSUE

Glendoe shut over tunnel rockfall

A rockfall near the top of the headrace tunnel has resulted in a blockage that last month led Scottish and Southern Energy (SSE) to shutdown in relatively new hydropower plant at Glendoe, Scotland, while investigations get underway.

The rockfall partly blocked the tunnel but had not caused equipment damage in the underground powerhouse when the problem was discovered, the utility said. Its adviser is Jacobs.

Glendoe, which commenced operations only at the end of last year, has more than 16km of tunnels, including a 6.2km long headrace that links the power cavern to the reservoir. There is also a 6.9km long aqueduct tunnel in the upper catchment.

The tunnels were mostly excavated by drill and blast though a TBM was used for the headrace excavation by the design and build contractor, Hochtief Glendoe JV which includes Poyry.

A 5m diameter TBM (Robbins hard rock machine, refurbished and hired from Herrenknecht) was used to drive the headrace through geology comprising schist and quartzite, with minor faults and little water ingress.

Lining support comprised bolts, steel ribs, mesh and shotcrete as required. The drive was completed in January 2008.

It was not known if the rockfall was in the shield bored section, drill and blast or other excavated stretch that links the top of the headrace to the reservoir.

Singapore's Circle Line dug

Singapore has completed tunnelling work on the new 33.3km Circle Line. The Land Transport Authority announced last month that Stage 4, the final of five stages to be completed, broke through into Farrer Road Station on 17 August.

The Line is an orbital, medium capacity line that links all mass rapid transit lines running into the city. The first five stations from Bartley to Marymount opened in May 2009 while the remaining 24 should be fully operational in 2010.

The US$4.4bn project became famous in 2004 for the Nicoll Highway collapse when a tunnel support structure within one of the open cut stations on the Circle Line Extension gave way. The resulting 30m collapse spread across six lanes of Singapore's Nicoll Highway, killing four people and injuring three (*T&TI*, February 2007, p31).

Singapore's wide range of rapidly changing geology makes the local underground conditions difficult to predict. On Stage 4 of the tunnel alignment, the engineers encountered extremely fine and soft soil, weathered rock and exceptionally strong granite.

"To overcome this challenge, a more advanced model of TBM - the slurry machine, was introduced to cope with the difficult geology. To further enhance the safety of the works, LTA carried out extensive investigation of the subsurface conditions along the tunnel alignment and whenever necessary, improve the ground," explained Karen Ng, spokeswomen for LTA.

Tunnelling at this stretch of the Line consists of four drives. The two drives from one-north to Haw Par Villa were completed in February 2008. The other two drives, from one-north to Farrer Road station, driving through Buona Vista and Holland Village stations, battled through many challenges on their way towards the Farrer Road station.

Stage 4 was broken into two contracts. Tai Sei Corporation used a TBM from Kawasaki to bore the Thomson, Botanic Gardens, Farrer Road Stations leg. A JV of Woh Hup/Shanghai Tunnelling/Alpine Mayreder handled the rest of the bore with a TBM from Herrenknecht.

Of the remaining 24 stations still under construction, Kim Chuan Depot and five stations [Dhoby Ghaut, Bras Basah, Esplanade, Promenade and Tai Seng] have achieved Temporary Occupation Permits. Some 76 per cent of the railway tracks have been laid.

Line 2 breakthrough in Wuhan

Wuhan underground metro's TBM has been re-assembled and is ready to launch for the return drive on Line 2 of the rail project. The 6.28m diameter EPBM delivered by NFM Technologies to contractor B1 finished excavating the stretch from Fanhu station to Qingnianlu station north of the city in June.

The machine bored at an average pace of 70m a week with the peak week seeing 93m of tunnel excavated through the water-saturated clay. The TBM arrived on site in early 2009 and launched in March. It took just three months to bore the 1068m drive.

Wuhan, located in the east of China on the Yangtze river, started construction of Line 1 of the metro system in December 2000 and began operation in July 2004. Three further lines are under construction, Line 1 phase 2 and the first phases of Line 2 and 4, at the cost of US$4 bn.

A view down the 33.3km long Circle Line

Workers celebrate the final breakthrough on Stage 4

Impregilo set for Abu Dhabi tunnel win

Italian contractor Impregilo is set to be the first company to win one of three contracts for sections of a 42km sewer tunnel for the Abu Dhabi Sewer Services Company (ADSSC).

The news was revealed prematurely by the Abu Dhabi Executive Council which confirmed Impregilo as the winner in mid August but according to client ADSSC the contract award letter is yet to be issued.

The Executive Council is a council of senior ministers chaired by the Crown Prince of Abu Dhabi Sheikh Mohammed bin Zayed Al Nahyan. It approves all project and financial decisions made by the Emirate's various authorities – including ADSSC.

"The Executive Council of Abu Dhabi has awarded Impregilo an US$243M contract to construct a sewer tunnel linking Abu Dhabi Island and mainland to sewage treatment plants in the Emirate," it said in a statement.

Impregilo declined to comment but contractors bidding for the project said that they were surprised to see the council making an announcement before the award letter was sent. "We have all seen the announcement but have not yet been told this is the case by ADSSC, I think even Impregilo were surprised," said one bidder. Confirmation by ADSSC is not expected until mid-September.

Abu Dhabi's new sewer is part of the emirate's US$1.6 bn 'strategic tunnel enhancement programme' (STEP) designed to replace the existing pumped wastewater network with a new gravity sewer system. A total of seven contracts will be awarded including three for the main 42km sewer, three for the connection pipework and one for a new pumping station.

The main bore will run from Abu Dhabi island in the north down to the Al Wathba sewage treatment works on the mainland in the south. The 42km tunnel has been split into three contracts and three further contracts for the connecting sewers are yet to be tendered. A final contract for the pumping station that will lift the effluent into the treatment works is currently out to tender.

The main tunnel is to be constructed in three sections starting at a depth of 20m and graduating to 80m at the pumping station. Design velocities for the wastewater are 18.4 cubic metres per second and maintenance tunnels will be constructed at 2.5km intervals.

Section one is a 17km section from Abu Dhabi Island to Mussafah on the mainland and will have a 4m internal diameter. Section two, to be built by Impregilo, running from Mussafah to Mafraq is 14.5km long with a 5m internal diameter and the third section from Mafraq to the sewage treatment works at Al Wathba will be 10.5km and have a 5.5m internal diameter.

A total of eight EPBMs will be used on the bore. The three 5m diameter, three 6m diameter and two 6.5m diameter machines are set to remove 1.2million cubic metres of fill. Contractors are expected to bore through the sandstone, mudstone and gypsum at rates of 100m per week.

Three metre diameter connection sewers will be installed by pipe-jacking from manholes at 300m centres at a depth of 10m to 25m. The first contract will be for pipes on Abu Dhabi island, the second for the mainland section and the third contract will be for the eastern areas of Saadiyat Island and Al Raha Beach.

Currently the ADSSC treats more than 450,000 cubic metres of wastewater every day using its pumped network and by installing a gravity system the authority can eliminate 26 existing pumping stations and in turn reduce operational costs and energy use.

Maintenance costs are also being kept as low as possible by using a dual corrosion protection liner of 2.5mm high density polyethylene cast into a 225mm in-situ concrete secondary lining. Pre-cast segmental concrete sections will form the primary lining.

Nine contractors are understood to have bid for the three tunnel sections including Germany's Bilfinger Berger, Brazil's Odebrecht, French firm Bouygues, Australia's McConnell Dowell, Korea's Samsung, local UAE firm Lindenberg-Emirates, Italian Astaldi and Germany's Ed Zueblin. Project manager is CH2M Hill.

Tyne tunnel gets dredging

Dredging for the second Tyne Tunnel will launch this month, after contractors last month got the go ahead from the Environment Agency. The dredging will make way for the tunnel sections to be immersed into later this year.

"Previously the government had made it a condition that the dredging should take place in the winter months to avoid the salmon migration season," explained a spokesman for the EA. "However, new methods of both dredging and disposal mean this important operation can now be brought forward," he added.

A suction-cutting dredger will suck sediment and water up and reduce the amount of silt that would be disturbed by the more usual bucket or 'back-hoe' dredger. The silt will be piped 1.5km downstream an enclosed pipe system, and used to fill the now redundant Tyne Dock. This disposal will avoid an estimated 4,600 lorry journeys through built-up areas, and also means there will be no dumping at sea.

All four 90m long concrete elements have been completed and the ballast tanks were last month being tested and the bulkheads, which will seal the elements for floatation, were being erected.

The works are being carried out by a JV led by Bouygues Travaux Publics and including High-Point Rendel, Parsons Brinckerhoff, Faber Maunsell, Able UK, Clancy Docwra, Wood Holmes, Hall Construction, Insite Environments, and Colas. The client is the Tyne and Wear Passenger Transport Authority (TWPTA).

A suction-cutter will be used as shown on the Limerick Tunnel

Poor rock kills Sparta deep hydro plan

Poor geology has forced US hydropower developer Riverbank Power Corp to cancel its plan for a major underground complex near Sparta, New Jersey.

Riverbank said that analysis of early data from the initial drill tests at Limecrest Quarry site showed the proposed site to be unsuitable for the grid of tunnels and caverns. The project was announced at the beginning of the year (*T&TI*, February, p14).

Excavations would have taken place at a depth of 610m to hold a powerhouse and enable water to be circulated in a closed-loop with the flooded quarry above.

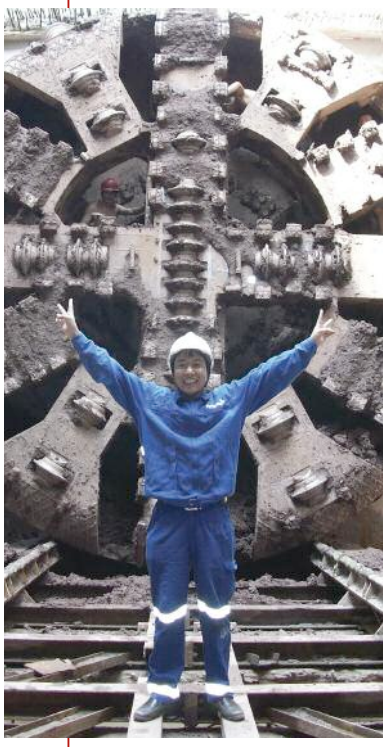
The design of the standard, "Aquabank" pumped storage package would provide a large power capacity facility (1GW) for a private equity spend of US$2bn. Construction would take four years.

Backed by venture capital firm Blackrock, the company is planning a series of large pumped storage projects across the US and Canada. Riverbank said Limecrest Quarry was one of the top sites in its development list and despite the failure of the location it is pursuing other options.

The other key project under development at present, and which has showed good geological results so far, is at Wiscasset, Maine. To be excavated also at 610m depth, the tunnel complex would hold the lower reservoir and powerhouse, and water would circulate with a tidal river above.

The Wiscasset facility is planned to come into service in 2014, should further site investigation of the schist rock, known as the Cape Elizabeth Formation, also prove satisfactory.

Riverbank and Blackrock are pursuing the standardised underground hydro schemes as pumped storage is a fast-response system to help dynamically balance power in transmission grids. The closer they are to load centres of the grid, especially where there is a lot of wind power facilities, the more valuable the projects would be to grid owners.



A worker celebrates the intermediate breakthrough

TBMs full ahead on GuangFo Metro

Tunnel boring is racing ahead on the Guangzhou-Foshan Metro Line in China. The first of two Robbins EPBMs working on the project achieved an intermediate breakthrough in August more than a month ahead of schedule. It is now waiting for the shaft to be readied before it bores a further 700m to complete the drive. The second EPBM is expected to breakthrough in October.

The machines are boring parallel 2.6km long tunnels for the Guangfo line of the new metro, which will connect the neighbouring cities of Guangzhou and Foshan. The line is part of the Chinese government's Inter-city Rapid Rail Project, which aims to link up nine cities in Guangdong Province by 2015, including Shenzhen and Dongguan.

The 6.3m diameter machines have been boring for seven months through ground conditions of weathered granite, coarse sand, and silt with earth pressures of up to 4 bar. Four independent foam injection points in the cutterhead are being used to consolidate the face and create a smooth flow of muck in the mixed ground conditions. Active articulation systems have also allowed the machines to make curves down to a 200m radius with no ring deformation. This type of articulation allows the front shield to turn independently of the machine's thrust cylinders, applying even pressure to each ring in tight curves.

The machines have out performed the other 16 TBMs on the project according to manufacturer Robbins setting a best month drive of 377m. "The excavation speed of these machines has been praised by the project owner, Guangzhou Metro Company, many times. We believe the high rates are a combination of fewer equipment failures and efficient project management," said Mr. Ju Yicheng, Vice Chief Project Engineer for contractor China Communication Construction Corp., 2nd Navigation Engineering Bureau (CCCC).

Safety Passport launch

The National Specialist Training Forum for the UK Tunnelling Industry TunnelSkills will this month launch the tunnel industry's own Safety Passport scheme. The tunnel passport was called for as industry leaders feared the ramp up in tunnelling work with Crossrail and Thames Tideway coming on stream would increase the risk to inexperienced labour.

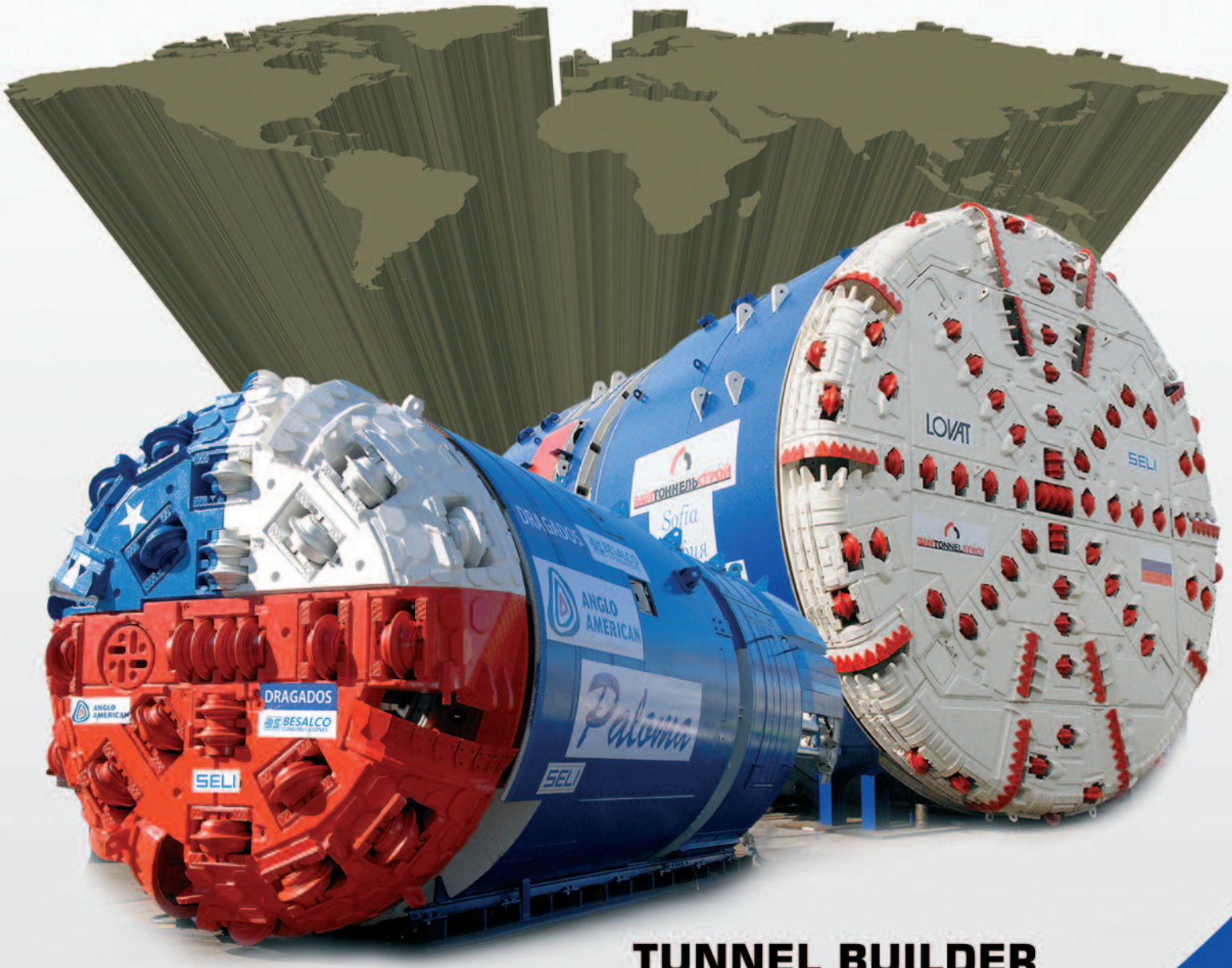
"It was recognised that to safely deliver these and other UK tunnel projects, inexperienced workers entering this potentially high-risk sector required a better understanding of modern tunnel construction techniques and the specialist hazards these bring," said TunnelSkills chairman Robert Ibell.

The plan is for all tunnelling personal staff to undergo a one-day health and safety training and assessment to ensure they understand the dangers of working underground. The Passport will also be the first stage of a National Vocational Qualification in Tunnelling Operations.

Trials for the training days were carried out to develop the syllabus, which now includes practical techniques for shaft sinking and the major tunnelling methods including TBM, Sprayed Concrete Lined, hand mining, pipe jacking and small bore tunnels.

The launch will be held at the BTS on 16 September.

Boring through future



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Fehmarn seabed SI underway

Seabed site investigation has begun for the Fehmarn Link between Denmark and Germany with a regime employing pairs of boreholes for separate soil sampling and strength tests.

The SI work got underway in July and it is expected that approximately 25 tonnes of samples will be taken over the next two years. The separate test system has been introduced to ensure the 1.5m long samples remain intact for extraction from the 100m deep boreholes.

Femern Baelt A/S will use the data, along with environmental surveys, to decide between rival immersed tube tunnel and bridge designs for the 18.6km long road and rail crossing.

A choice between the options is expected to be made in 2011 with construction due to started in 2012. The link is to open in 2018.

The tunnel design is being developed by a consortium of Ramboll Danmark, Arup and Tunnel Engineering Consultant (TEC), work having started in the second quarter.

The design work is supported by a team of subconsultants – WTM Engineers, HTG Ingenieurburo fur Bauwesen, Wilkinson Eyre Architects, Schonherr Landskab and Oriental Consultants.

TBMs signed off for Airport Link

The team constructing the major infrastructure development in Brisbane have approved the two EPBMs that will bore the Airport Link. Engineers from Thesis John Holland singed off the two machines at Herrenknecht's German factory and expect the first on site in December for launch in May next year.

The pair of 12.48m diameter hard rock TBM were ordered last year with contract value of more than US$64M. The TBMs will drive parallel tubes southbound from Toombul to Bowen Hills for the project's 5.25km long toll tunnel, which dominates the 6.7km long link.

Tunnelling works are progressing rapidly on the Airport Link. Tunnelling was 25% complete at the start of August, with nearly $1bn in total already expended on construction activity. 24-hour tunnelling continues at Bowen Hills, Kedron and Windsor precincts of the project.

Tunnelling at Truro Street, Windsor - the project's mid-point tunnelling site - is well advanced to the mainline tunnel, 40m underground. "This has allowed the first two of four roadheaders to begin excavating in North and South directions. Southbound tunnelling has progressed more than 50m," explained a TJH spokeswoman.

Tunnelling continues at Bowen Hills from the Federation Street site with roadheader excavation of the northbound tunnel progressing more than 120m.

The Airport Link is part of Brisbane City Council's TransApex plan, which also includes the 1.2km Northern Busway linking the Royal Children's Hospital with the Bracken Ridge development.

Left: One of the two Herrenknecht machines to be used in Brisbane

Works start on MTR WIL

Works kicked off on the MTR West Island Line in Hong Kong last month with a breaking ground ceremony. The US$1.98bn (in Dec 2008 prices) WIL project is a 3km underground extension of the existing MTR Island Line from Sheung Wan to Kennedy Town, via two new intermediate stations at Sai Ying Pun and the University of Hong Kong. It is due for completion in 2014.

MTR Corporation (MTRC) earlier this year received approval for funding of WIL, and has also signed a deal to take forward involvement in Shenyang metro (*T&TI*, July, p14). The Executive Council of Hong Kong in June endorsed the scheme and with the greenlight from the Legislative Council construction is getting underway.

Six civil construction contracts for the first stage of works, including the access shafts, have been awarded since the project agreement was signed in July. The winning tenders were not available as *T&TI* went to press.

"Further contracts for the West Island Line project will be awarded progressively over the next few months. Construction in the densely built-up Western District poses significant engineering challenges," said Russell Black, Projects Director of MTR Corporation.

Above: Wet feet for workers celebrating the breakthrough

Breakthrough at Sugarloaf

A 830m long pipejack for the Sugarloaf pipeline, part of water transfer project in Victoria state, Australia, has holed through after a rock and soft ground drive.

John Holland used a Herrenknecht AVN 1800 TD, with an extension kit, to install 2m i.d. pipes with 200mm thick walls.

The pipejack was excavated through 700m of rock with strengths of 80MPa-250MPa, and 130m of soft ground. Much of the alignment was on a curve of radius 825m. Cover to the drive was up to 42m, and the head of groundwater was a maximum of 20m. Excavation work took 10 weeks.

The project was undertaken by the Sugarloaf Pipeline Alliance, which includes the contractor as well as Melbourne Water and consultants GHD/SKM. The pipeline, in Toolangi State Forest, is part of the 70km long Sugarloaf Pipeline which will transfer water as part of irrigation improvements.

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Victoria upgrade award nears after planning OK'd

The award of the tunnelling work contract on the Victoria Station Upgrade (VSU) project in London has taken a step forward with planning approval finally having been obtained.

London Underground (LU) will award the job under the NEC form of contract, on a target cost basis.

Bids for the contract were submitted a year ago from shortlisted parties but the progress of the procurement depended on the results of a public enquiry, which subsequently lasted three months and ended in January.

Following the issue of planning approval by the Government, a Transport and Works Act Order is being produced to authorise the works to be done. The Order is expected to be ready by this month. Then, subject to final funding approval by LU's parent, Transport for London (TfL), the contract is to be awarded and construction is due to start next year.

The project calls for the construction of a number of new passenger access tunnels, a new ticket hall and an enlarged ticket hall both built as open boxes. Most tubes will be about 6m high by 5.5m wide, though the cross section of the escalator barrels will be much bigger.

Most of the excavation will be above London Clay, in the waterbearing River Terrace Deposits.

The lead consultant for VSU is Mott MacDonald. Constructability checks were supported by London Bridge Associates and Gall Zeidler Consultants (*T&TI*, December 2008).

The VSU project is expected to take about seven years to be completed. The project is separate to the tube network upgrade programmes under LU's Public-Private Partnership (PPP) scheme. It is also unrelated to the Victoria Line upgrade.

Cavico wins hydro contract

Vietnamese infrastructure giant Cavico Corp. this month announced that it has boosted its work at Dakdrinh Hydropower Plant with the signing of a US$16M tunnelling contract. The contract for the construction of a 7.5km long and 4.5m wide water tunnel and tunnel Sections No.3, No.4, and No.5 was awarded to a JV of Cavico Transport, Licogi and Song Da Corp.,

Cavico Transport recently signed two separate contracts with Dakdrinh Hydropower for Phases I and II of the Dakdrinh hydropower plant project totalling US$13.4M to extract, process, and transport stones. The new win brings Cavico's total contracted revenue from the hydropower project to US$24.9M.

Owned by Dakdrinh Hydropower Company, the 125 megawatt hydropower plant is funded with US$212M capital investment and is located on the Tra Khuc River in Son Tan village in the Quang Ngai province of Central Vietnam. PetrolVietnam Joinstock Finance Corporation (PVFC) and the Bank for Investment and Development of Vietnam (BIDV) are committed to finance the project.

Florence rail bores for Seli

Seli has been awarded a subcontract to use an EPBM to drive two tunnels for a High Speed-High Capacity rail scheme in Florence, Italy.

A 9.4m diameter EPBM will be used to bore twin, 5.5km long tubes on the north-south section between Florence Rifredi and Florence Campo di Marte. It is to drive northwards, be dismantled at Rifredi and returned to campo di Marte for relaunch.

Geology along the alignment comprises alluvial sediments, lake deposits and clay. The bores will be lined with 8.30m i.d. segmental rings (6+1) of 400mm thickness.

The twin tunnels are to be linked by 13 cross passages spaced at 410m-490m intervals.

The main contractor on the project is the Nodavia JV, which includes Coopsette, Ergon Engineering and Contracting Consorzio, and Coestra.

The contract value of the full scheme, including an underground station and an elevated stretch of track, is US$1.3bn. The project is to be completed by mid-2014.

Cairo metro TBM order for NFM

NFM Technologies is to supply an EPBM, due for delivery to site in the second half of 2010, to the Vinci Construction Grands Projets-led JV building the Phase 2 package of Cairo metro's Line 3.

The 9.46m diameter TBM will be used to drive through clay, sand and sandstone. The JV wants the machine to be adaptable for possible later use in slurry mode excavations.

The JV – comprising also Bouygues, Arab Contractors and Orascom Construction Industries (OCI) – is building a twin-track, single tube with four stations under a 51-month contract. The stations on the Abbassia-Heliopolis section are Cairo Fair, Cairo Stadium, Kolleyet El Banat and Ahram St.

Boring from Cairo Fair to Kolleyet El Banat, the EPBM will drive 5,138m to link the three stations. After fit-out, the new section of Line 3 is to be in service by the end of 2013 (T&TI, July).

The same partners are also working as a JV to build the Phase 1 package of Line 3, which is the Abbasia to Attaba section. The JV is using a refurbished 9.5m diameter Herrenknecht slurry shield to drive the tube linking five stations – Abbasia, Abdou Pasha, El Gueish, Bab El Shaaria and Attaba.

Geology along the alignment of the 4.2km long single bore comprises backfill, clay, sand and gravel.

Gammon, Leighton wins HK sewer jobs

Contracts worth a total of US$813M have been awarded to Gammon Construction and a JV led by Leighton, respectively, to build 19.5km of deep sewers for the second stage of Harbour Area Treatment Scheme (HATS 2A) in Hong Kong.

Gammon Construction was awarded a contract (DC/2007/23) of US$485M to construct approximately 12km of sewer tunnel at depths up to 165m, and eight shafts.

Three tunnels are to be built by drill and blast excavation between North Point and Stonecutters Island. Excavated spans will be 4m-5.5m.

Separately, a contract (DC/2007/24) worth US$328M was awarded to a JV of Leighton Asia and Leonhard Nilsen & Sonner.

The 80:20 JV will build 7.5km of tunnel at depths of 70m-120m. The sewers will be built from Aberdeen to Sai Ying Pun on Hong Kong Island.

The contracts were awarded by Hong Kong government Drainage Services Dept. Design and construction supervision services to the works are being provided by Aecom Asia.

At the end of last year a JV of Leighton Asia and John Holland was awarded a contract to design and build two stormwater sewer tunnels for the Lai Chi Kok section of the grid. The 4.9m i.d. sewers have a total length of 3.7km with six intake shafts, are up to 80m deep (T&TI, December 2008).

Separately, the Drainage Services Dept has called for bids to build approximately 6km of sewer tunnel for the Tuen Mun Western section of the network. The rescheduled deadline for tenders is 18 September.

Crossrail starts build bid calls…

Crossrail has called for expressions of interest for two tunnelling contracts (East, West packages) on London's major transport scheme. It also refined its requirements calling for six EPBMs – one less than previously planned.

Already a JV of Balfour Beatty, Beton-und Monierbau, Morgan Est and Vinci has declared its plan to bid, as the BBMV group. They would be supported by subsidiary businesses, including Bachy Soletanche, Balfour Beatty Ground Engineering and Morgan Est Piling.

Deadline for expressions of interest for the packages – C300 (Tunnels West) and C305 (Tunnels East) – is 18 September. Crossrail plans to call for bids around November and plans to award the contracts by the middle of next year.

The contractors are to design and build a segment factory at a site to be chosen by the client. Main tunnel excavation on the US$25.8bn scheme is to commence in late 2011. It was earlier penciled in for a mid-year launch when seven TBMs were being considered.

A total of 41.5km of tunnel is to be constructed for the twin-bore rail link that will run through the centre of London. The two TBM drive packages will cover a total of 36.2km, or 87%, of the tunnel build.

The C300 package calls for construction of twin TBM drives over a stretch of 6.2km from Royal Oak and a Portal near Paddington, in west London, to Farringdon. Crossrail said the tunnels will be 6.2m diameter, slightly larger than the earlier noted plan for the nominal 6m i.d. bores.

In the east of the city, the C305 package involves excavation of three stretches of twin tubes with lengths of 8.3km (Limmo to Farringdon), 2.7km (Stepney Green to Pudding Mill Lane Portal) and 0.9km (Limmo to Victoria Dock Portal).

Royal Assent for the project was granted in 2008 and rail services are due to start in 2017.

… as more design contracts awarded

Design contracts worth a total US$9.8M for three tunnel portals and US$66.7M for four central stations have been made on the Crossrail project to five different companies.

Hyder has been awarded two design contracts – Victoria Dock Portal (C154) and Whitechapel station (C140). The contracts are valued at US$4.4M and US$16.5M, respectively.

Capita Symonds has been awarded a design contract covering two tunnel portals, at North Woolwich and Plumstead (C156). The value of the contract is US$5.4M. It already has the US$4.9M contract for Royal Oak Portal (C150).

Mott MacDonald was awarded a US$18.4M design contract for Liverpool St station (C138). The company already has the US$14.6M contract for sprayed concrete lining design (C121), the tunnel M&E contract (C125) and the tunnels and shafts aerodynamics and ventilation contract (C124).

The design contract for Paddington station (C130) was awarded to Scott Wilson. The value is US$16M. The firm already has contracts for Farringdon station (C136) and Pudding Mill Lane Portal (C152).

WSP was awarded the design contract for Bond St station (C132). The value is US$15.8M.

Other contract winners have included Arup with Atkins, and also Jacobs.

The twin bores are being designed by Arup/Atkins under their contract (C122) worth US$27.7M. The pair also has a US$16.3M contract for Tottenham Ct Rd station (C134).

Jacobs has the Intermediate Shafts contract (C123). Separately, supported by KPMG, the firm is also acting as Project Representative for the Department for Transport (DfT).

Other companies with key roles in the scheme to support the client include the Project Delivery Partner (Bechtel, supported by Halcrow and Systra) and Programme Partner (Transcend – a JV of Aecom, CHSM Hill and Nichols Group).

The Mayor of London also recently announced a levy to fund London's share of the transport scheme.

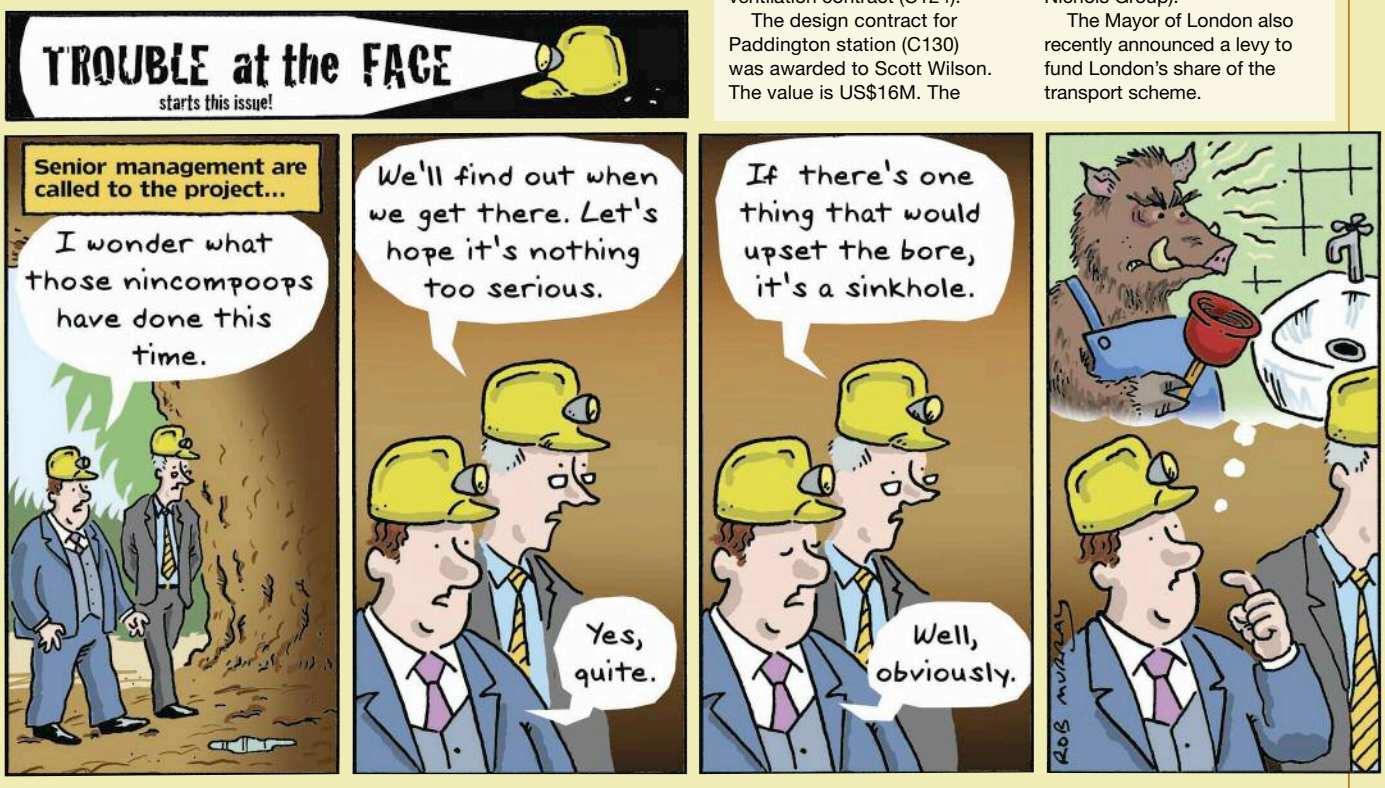

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Photo of the immersed tunnel site

Cracking on

Controlling concrete cracking is the key to building a watertight immersed tube tunnel without adding waterproofing. Jon Young looks at how the Limerick Tunnel team handled the challenge

The mating habits of the North Atlantic Salmon have dictated almost every step of construction of the crucial Southern Ring Road on the outskirts of Limerick in Ireland. And despite this the project is unofficially anticipating an early opening.

The tolled road project will bypass Limerick on the south west side with the critical new river crossing promising to relieve the city of mounting congestion. Almost the entire road project's schedule hangs on the construction of its most important feature: a 675m immersed tube tunnel under the River Shannon. As the most complex part of the project, works on the tunnel have set the pace for the entire job. And with an embargo on the dredging, floatation and immersion of the tunnel units while the Salmon is in season, this fish's up stream struggle has set the schedule for tunnelling works.

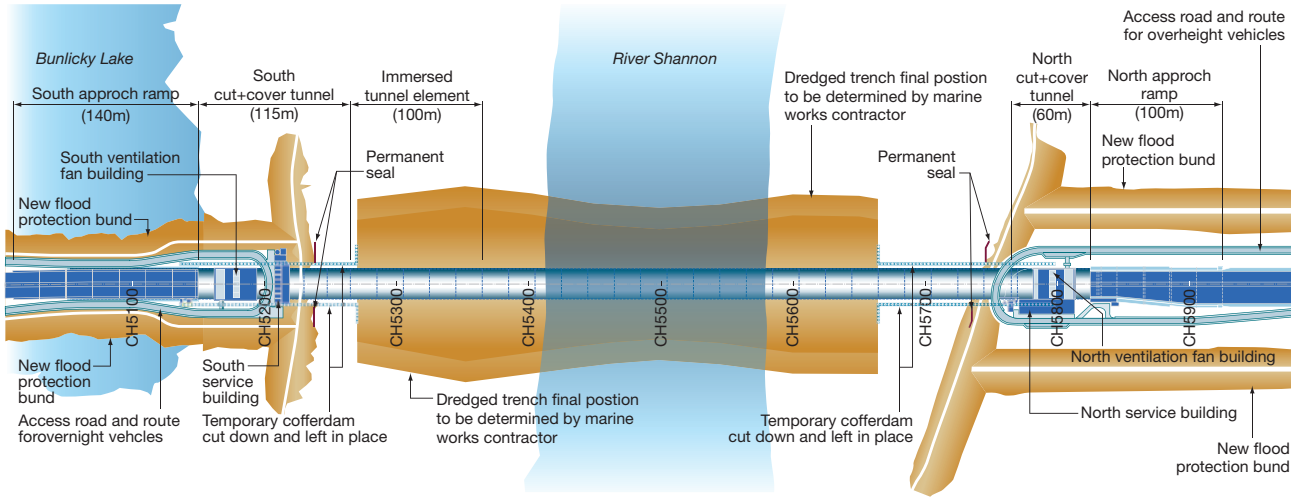
Consultant Capita Symonds has designed every detail of the crossing for the construction joint venture and remained on site to assist contractor Strabag with the works. DirectRoute, the construction JV of Allied Irish Banks, John Sisk & Son, Lagan, Meridiam Infrastructure Finance, Roadbridge and Strabag, signed a Public Private Partnership (PPP) agreement with Ireland's National Roads Authority (NRA) in August 2006 for the 30 year construction, operation and maintenance concession for the Limerick Tunnel.

Temporary solution

The onsite casting basin is arguably the most significant piece of temporary works on any immersed tunnel project. Its location varies depending on the available space around the tunnel. At Limerick the basin was dug in line with the tunnel extending from the north end entrance some 560m.

The site was situated almost entirely in soft alluvium making robust temporary works a significant challenge. Project

Below: Fig 1 – Plan diagram of the tunnel and approaches



director for DirectRoute Mike McGuire explains, “The first 12 months of the program was just getting the casting basin ready… there is sheet piling all the way down each side and across the back on the north side. It was built in two levels, the lower level was sheet piled and the upper level we shaped.”

The basin was some 30m wide to give enough space to construct the 25.25m wide tunnel elements. A cofferdam wall made of Combi piles separated the south end of the casting basin from the Shannon.

A similar, though shorter, working area needed to be dug on the south side to construct the adjoining cut and cover tunnel. McGuire says, “The south cut and cover was a tricky challenge. We had to build it on what was basically just a strip of land between the river and [Bunlicky] lake.

The team had to dig down through the 5m flood protection to about -10m. The cofferdam was over 130m long and 30m wide. The Combi wall holding back the river on the south side was strutted at the top and a cast underwater slab acted as a prop at the bottom. The slab would later form a base for the cut and cover tunnel.

Speedy excavation of the basin and the south cut and cover tunnel was essential to keep on schedule. A 120m stretch of rock from the north side of the casting basin gave ready ground for the casting of the first of the five elements ahead of schedule.

The right cast

There are two ways to cast an element, according to McGuire. “You can do it segmentally, as we’ve done, or you can do it as one single monolithic element. But as one element there are higher stresses in the tunnel. Because of the larger stresses it is more prone to cracking. Because of the cracking it has to be waterproofed all the way round. It becomes very difficult.”

Breaking the 100m long element into five 20m segments drastically reduces the stresses in the element. With the risk of cracking reduced the waterproofing can be eliminated. However, without the final waterproofing it is crucial that cracking is controlled at all stages of construction.

Cracking is most likely to occur during the casting phase due to the heat generated as the cement in the concrete hydrates and in the casting of the first segment it appeared to be a more complicated issue than anticipated. Piping cold water through the segment cooled it but cracks still occurred.

Trevor Bone, site representative for designer Capita Symonds, explains, “When you design the cooling required to eliminate cracks you need to calculate the various properties of the concrete. There are a number of properties, some of which require quite long and expensive tests to establish values for a given mix. One of these properties is called autogenous shrinkage, which most people wouldn’t have heard of.

“When you design your concrete mix you try to minimise the amount of water because it gives you a more durable concrete. But there are problems which arise if you reduce this by too much. You could reduce it to a state that the mix doesn’t have enough water to react. That limit is a water/cement ratio of about 0.42.

“Below 0.42 there is not enough water in the mix for all the cement to react so there is some cement that’s not gelled. That leads to surface tension within the mix causing the concrete to shrink.

“So with these low water ratios there is a tendency for autogenous shrinkage to happen, even if the w.c. ratio is above 0.42 because not everything is mixed 100 percent. No matter how much you cool, this shrinkage will still happen. Shrinkage that can be controlled by cooling is over and above this.

“If you can assume you can accept so much shrinkage without the cracks developing and 50 percent of the shrinkage is autogenous shrinkage then you’ve got hard work to control the rest with cooling.

Bone adds that on the first segment “initially we agreed to use what we believed was a conservative value for the autogenous shrinkage. But when some cracks were found on the first segments it was accepted that further testing was required. These results indicated that the effect of autogeneous shrinkage was bigger than we had been assuming. The mix was changed to one with a lower autogeneous shrinkage value and this helped to control cracking.”

Altering the mix can also help reduce the heat the concrete emits as it cures. This heat is a major cause of cracking during the casting process and needs to be carefully controlled according to McGuire.

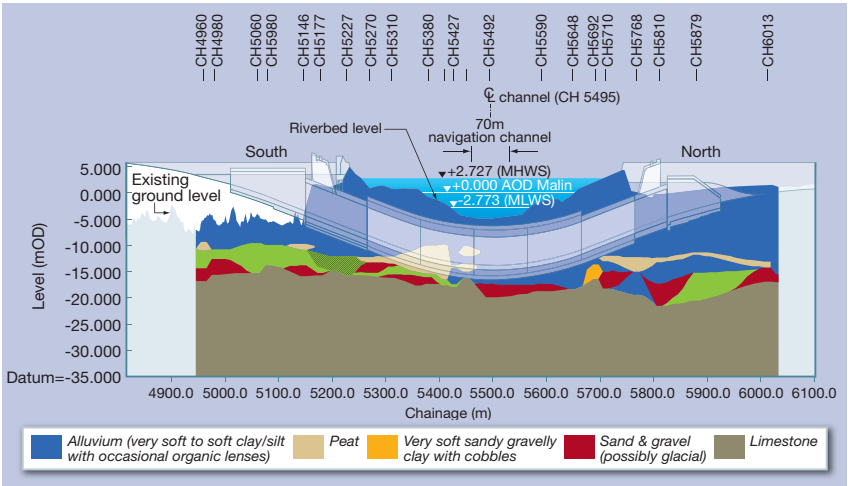
Following the first segment the team also beefed up the cooling system to help reduce cracking. McGuire explains, “Cracking is unavoidable but through cracking is a problem, we were not permitted through cracking under the contract. A lot more cooling was needed than we originally anticipated to prevent the concrete from cracking. There were 29 pipes running through each segment, pumping water through for five or six days.”

Crack mapping of the inside and outside of the element gives a good indication of where through cracking has occurred. Where cracks have appeared they need to be sealed. Bone says two different grouts are being used to get a watertight seal, “one is a polyurethane grout and the other is an acrylic based grout. The acrylic based grout is less viscous and so can fit into smaller cracks.” A small hole is drilled into an area where cracking has appeared and grout is injected in until it flows out of all the cracks.

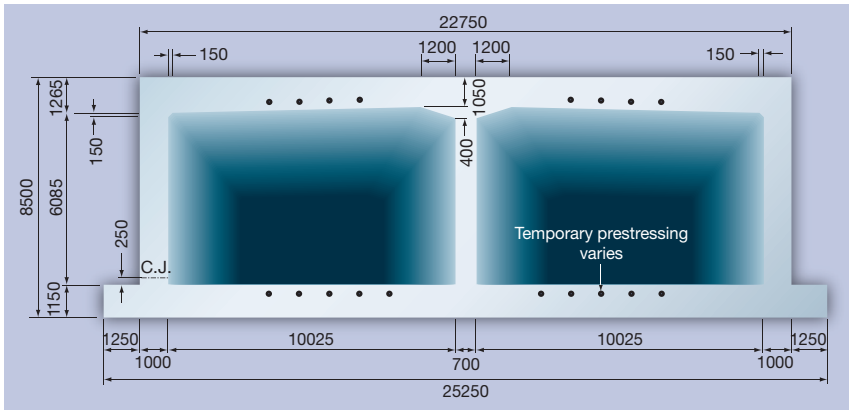
Floating tunnel

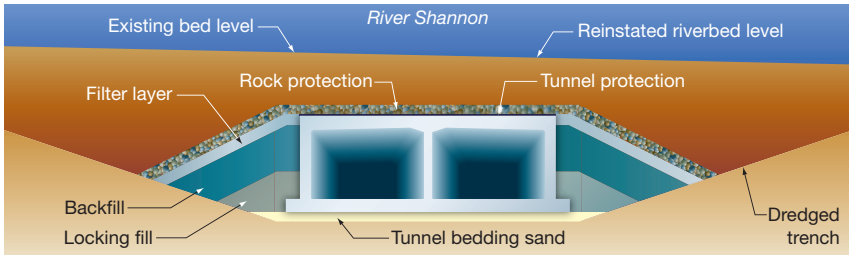
Before the elements could be floated into the river a trench had to be dug for them to be lowered into. McGuire explains, “We couldn’t physically start the dredging during February, March or April, as there was an embargo on the river because of salmon. Our whole program was built on the 1 May when we could start dredging. We worked out how long we’d need to dredge and from that based the program.”

The dredging started in the beginning of May and continued to the end of July with the suction-cutting dredger removing silt in stages and pumping it into settlement basins



Left: Fig 2 – Long section of the tunnel and geology





Left, top: **Fig 3 – Tunnel cross section**
Left, bottom: **Fig 4 – The tube in-situ**

on the north side of the river. The water in the settlement basins would slowly make its way back into the river.

"The trick with dredging is to leave it as late as possible because of siltation. The movement of the river will force silt back into the trench you've just dug," says McGuire. Following the dredging and the trial flooding of the casting basin, on 8 September the project was ready to float the first element out into the Shannon.

A single 100m element weighs 20,000 tonnes. "When people joke 'will it float' you hope it will", says McGuire. Steel bulkheads seal off each end of the element. Wooden ballast tanks with a plastic lining are filled with water inside the element to keep it on the floor as the casting basin is flooded with water from the river.

During the flooding of the basin each tunnel element was weighed down with 2000 tonnes of water in the ballast tanks. Engineers calculated the weight of each element from core samples taken during construction. When the basin was flooded and the element was ready to be floated out into the river the ballast water was removed. Without the ballast the element had a buoyancy of about 1200 tonnes. This gave the element a free board – the height of the element above the water – of about 300mm.

"It took three months from the casting of the last element to the start of floatation." Having used an inline casting basin the last element cast was the first to be immersed.

All the earlier efforts to calculate the geometry and the displaced volumes are tested when the ballast tanks are emptied and the element floats. There are no reinforcing bars holding the five segments that make up the element together but eight prestressing tendons run through the roof and 10 run through the base to give the element rigidity for floatation and immersion.

"When the elements are being floated out and immersed they are under dynamic conditions," explains McGuire. "The prestressing tendons get cut once the element is down on the final bed. We cut at each of the segment joints to destress it. Those joints are then allowed to articulate." A shear key is cast at the segment joints when the elements are in place giving a mechanical connection between them.

"Immersing the elements was the high risk part of the project," says McGuire. "We had planned for [a maximum] 3m per second, if it exceeded that we'd have to standby."

"The element waits in the float out channel and we sit and have go/no-go meetings for each stage of the process. It was go/no-go from taking it out of the casting basin to the fit out area, which took about 24 hours and then we had a go-no-go meeting to take it into the river," explains McGuire.

The crews floated and placed one element a week until it came to the fifth element which had to wait three weeks, "The last element wasn't going into the river but was going into a very tricky location on the north cut and cover so we had to take time to change the arrangements we had for that," says McGuire.

Divers guided the elements into place for the last five hours of floatation. The allowed deviation from plan was 20mm. As the elements were sat together a Gina gasket created a seal. "The gasket has a soft rubber tit on it," says McGuire, "the element is moved forward with hydraulics sealing the joint on all sides. You are left with water on both sides of the seal. It won't close any further because you can't compress water, so you get a touch seal but no tighter no matter how much you push it." A bleed valve in the bulkhead is then opened and the chamber between elements is pumped dry.

As the element is sat on the riverbed it is placed on temporary jacks leaving a 800mm nominal gap underneath for sand bedding to be pumped into. Pipes cast in the element carry the sand to the bed. Divers open and close valves along the pipes to regulate the flow of sand.

Fair exchange

While the sand flow is being managed the element is still only on the riverbed because of the 2000 tonnes of water weighing it down. To make the tunnel permanently bedded it needs to gain weight.

"It's sat on a sand bed and we put fill material either side of it, known as locking fill. When all the elements are placed we start taking out the bulkheads one by one." The normal process would then be to pour concrete on the floor of the tunnel, for every tonne of concrete added a tonne of water could be removed. But on Limerick they identified a more efficient method.

"There is normally enough room on the floor to get enough concrete in to balance the load. We had actually very big tanks…so we deviated from the plan a little. We fully surrounded the tunnel with locking fill- this is not normally done because you want to lessen the dependency on the marine operation. The material above it could be counted as weight. Once we had that material on we emptied the tanks then put in the concrete ballast." The move made it much easier to place the concrete ballast as the crew was free to work in an open tunnel.

To complete the tunnel structural works, a second seal, an Omega seal, was placed in the joints between elements. "We do a 2.5bar pressure test to make sure there are no leaks in the seal. And finally the joints are concreted to create the shear keys between the elements."

Currently Strabag is finishing up on site while the mechanical and electrical works are carried out. The project is quietly hopefully that it will open in the first quarter of next year, about half a year ahead of schedule. T&T

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Cracking the problem

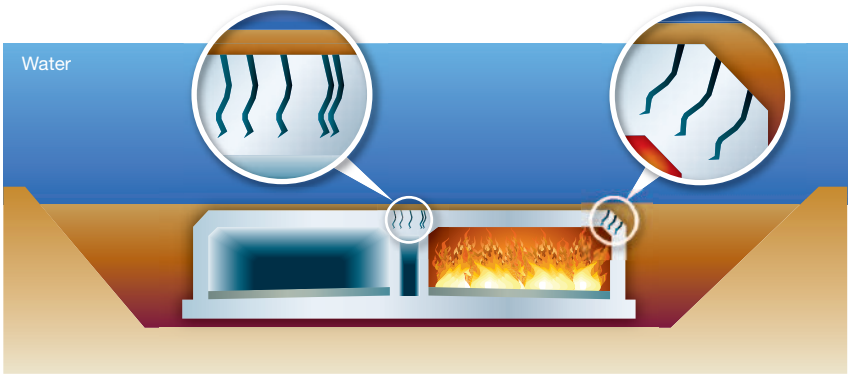
C. Both, A.J. Breunese, and P.G. Scholten, of Efectis Nederland, the Netherlands, describe an emerging problem for immersed tunnels - fire induced concrete cracking

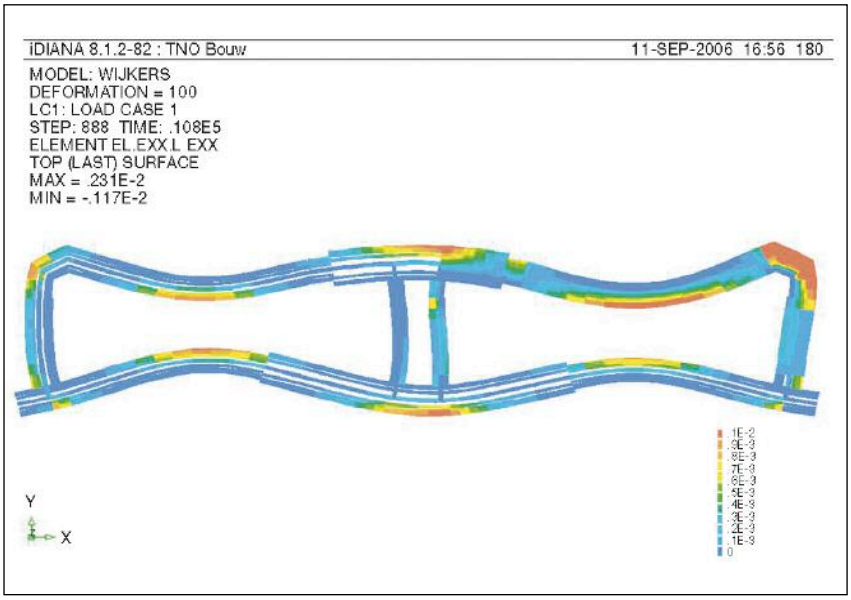
Immersed tunnels are widely used as an efficient tunnelling technique, to cross rivers and canals and even sea straits. The technique dates back to the early 1920's; old and recent examples of tunnels using this construction technique are: Detroit Windsor tunnel (USA), Oresund tunnel (Denmark-Sweden), Kennedytunnel (Antwerp, Belgium), Sydney Harbour tunnel (Australia), and the Maastunnel (Rotterdam, the Netherlands). Basically, prefabricated reinforced concrete segments are constructed in a dock and afterwards transported (floated) to the actual tunnel-site, where they are sunk and interconnected to form the actual tunnel.

In the last decade fire safety of tunnels has become a point of major international concern. One of the aspects that have recently been studied in this respect is the reparability of immersed tunnels after fire. Concerned about this issue, the Ministry of Transport in the Netherlands a couple of years ago commissioned a tentative study into the development of cracks in the concrete tunnel structure during fire. The study especially focussed on the unexposed (extrados) side of immersed tunnels, since at those locations repair options are limited. As an example in this study, the Wijkertunnel near Amsterdam was chosen. The study indicated the development of large and wide cracks on the unexposed side of the concrete, possibly yielding a durability problem on the longer term caused by collapse due to reinforcement corrosion. The uncertainties in the study where such that further work was found necessary, with a view to determine the severity of the problem. To this end, Efectis set out to study more in-depth the concrete cracking issue. This was done with fire tests, using 1:10 scale models of immersed concrete tunnels, along with the development of a finite element computer simulation model, validated on these tests, allowing for predictions of the behaviour on scale 1:1 and a parametric study. In two consecutive articles, the results of the study are presented. In this first article, the results of initial research and the scale 1:10 fire tests are presented. In the second article, computer simulations are discussed and final conclusions and recommendations presented. The results of the study are relevant not only for the industry involved in designing and constructing tunnels, but also for owners and AHJ's, with interest and responsibility for adequate fire safety assessments of immersed concrete tunnels. Full reports can be downloaded from the Efectis website www.efectis.nl, under the heading "news".

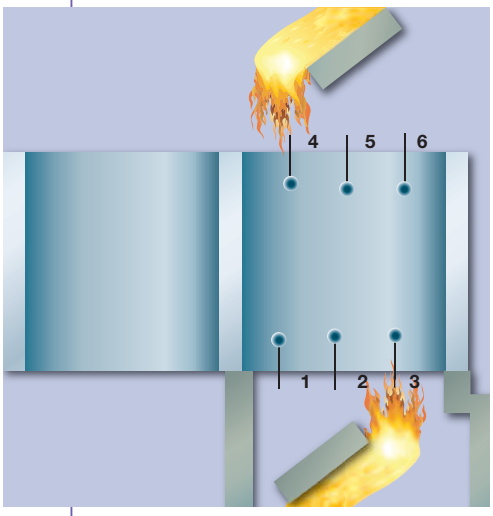
Initial research

The Ministry of Public Works in the Netherlands has been heavily involved in fire testing of concrete tunnels over the last decades. During these tests, apparent cracks became manifest at the unexposed sides of the tested specimens. Concerned about this issue, a tentative study was undertaken, using a simplified computer model (based on so called beam elements), with a view to further qualify and if possible quantify the gravity of the issue for typical immersed tunnels. The main focus was on the investigation of options for reparability of tunnel structures after fires. The study concluded that although deformations during and after severe hydrocarbon fires, resulting from e.g. truck fires and dangerous goods transport, may be negligible, severe





Right top: **Fig 1 – Problem identification**
Right, bottom: **Fig 2 – Computer model of a virtual fire in the Wijkertunnel**



Left: Fig 3 – Schematic top view of the test set up in the furnace. The scaled tunnel element is placed in the centre. Around it, an aerated autoclaved concrete compartment was built to create a compartment of the heated tube, the furnace walls, the gas burners and furnace exhaust holes. The deflected flames are also shown in the drawing, guided such that homogenous temperature distribution could be achieved. The numbers indicate furnace thermocouple positions
Below: Reinforcement and freshly cast scale model.

cracking must be expected at the unexposed sides of the tunnel structure[1] (figure 1).

In the initial study, a cross section of the tunnel was modelled, using simple beam elements. Some illustrative results are given in Figure 2, where strains in the concrete are plotted on the (exaggerated) deformed model of the structure. Red colours indicate tensile strains and blue compression.

From Figure 2 it may be clear that (assuming an RWS fire in the right tube) large tensile strains develop and concentrate at the unexposed sides, in the top right corner and above the middle tube (normally for services and evacuation). Crack widths were predicted to be in the order of magnitude of 1-2mm[1], even for tunnels with fire protection.

In depth investigation

The main question after the initial research was how to gain more insight and better quantify the gravity of the problem of cracking during and after fire. The following questions remained after the initial study:

- can we perform scale tests to illustrate the issue?
- can we further develop and sophisticate computer simulation models, calibrate them on the basis of (scale) tests and predict what could happen in reality?
- which parameters govern?

In addition to this there was a need to investigate the influence of adding polypropylene (PP) fibres to the concrete mix. These additions are becoming more common, especially to mitigate the risk of concrete spalling when exposed to severe fires. Although normally only applied for relatively high strength concrete in e.g. bored tunnels, PP-fibres are being used also with a view to create sacrificial linings in immersed and cut-and-cover tunnels, as an alternative to passive tunnel fire insulation for the protection of the steel reinforcement. For practical reasons, a scale 1:10 was determined, taking into account scale effects, cost-efficiency and handling options of (preparation of) test specimens.

Test specimens and test setup

A total of thirteen elements, concrete grade C28/35 were cast in the period February/March 2008: four without polypropylene fibre, and nine with polypropylene fibres, in which the type (make) of the fibres was varied as well as the diameter and fibre length. All fibres were dosed in 3kg/m^3 concrete.

All elements were scale models, approximately 1:10, with two tubes of (w x h) 1000 x 500mm and a length of 1500mm. The steel reinforcement consisted of two nets Ø 12-150mm with a cover of 35mm on both sides.

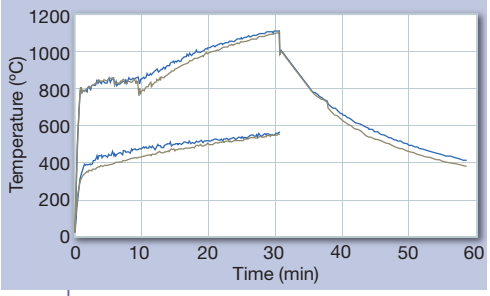
Ten elements were tested without fire protection on the ceiling. Three elements were protected with boards on the ceiling to simulate the practical situation. For these elements, the upper 10cm of the walls were also protected with boards. The tests were done in the period June/August 2008, aiming at more or less the same age of the concrete, with the exception of the first, trial tests performed in March 2008, on relatively young and fresh concrete (figure 3).

For the fire load, or applied temperature-time curves, an attempt was made to study the effect of both protected and unprotected tunnels and to try and reach the RWS fire curve, representing a fire resulting from an HGV or tanker (pool) fire. This appeared difficult, as can be seen in Figure 4, showing the temperatures in the heated tube. The two top curves indicate the maximum achievable average measured temperatures. The two bottom lines indicate temperatures applied in the tests representing the insulated concrete tunnel linings.

Three elements were subjected to a vertical load during the fire test to simulate the static ground and water pressure that is normally present on immersed tunnel elements. This was done, using concrete blocks with a total weight of 7560kg. During the test these measurements were made:

- Gas temperatures inside the scaled tunnel element
- Displacement of the heated tube at the middle wall, centre of the heated tube and the outer wall
- Cold surface temperatures on top of the element
- Temperatures of the interface between concrete and insulation, if any

Below: Fig 4 – Applied fire curves



Results of fire tests

Besides other cracks, main cracks become apparent in all cases: above the internal support wall, and in the side wall of the heated tube, as indicated in the photo (p21).

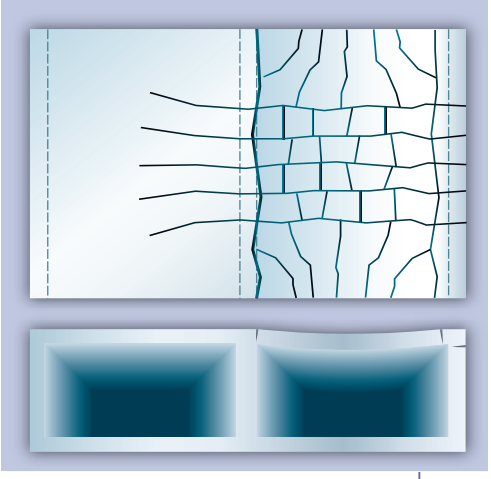
The parameters studied in the tests were:

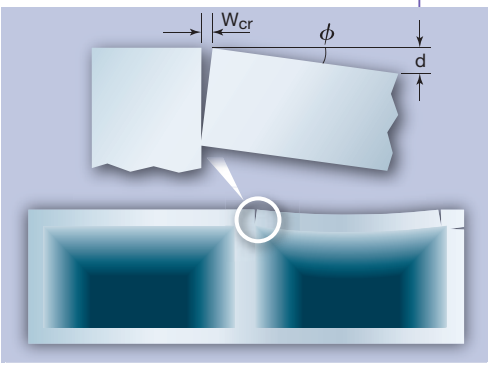
- With/without fire protection
- With/without PP-fibres
- Different types of fibres
- With/without vertical loading
- High/low fire temperatures

In Figure 5, the crack pattern similar in all

Table 1

	Vertical deflection	Crack width	Crack pattern	Moisture on cold side	Temperature on cold side
Fire protection/ lower heating rate	Less deflection +	Smaller crack width +	Smaller number of cracks, esp. in transverse direction +	No influence	Lower temperature
Adding PP-fibres	No influence	Smaller crack width. No influence of the type of fibre +	Larger number of cracks. No influence of the type of fibre –	Less moisture escaping on cold side	No influence
Higher vertical load	More deflection	Indirect information: as the deflection increases, the cracks above the walls must have been wider		No influence	No influence





Right: Typical crack patterns observed in the tests
Far right, top: Fig 5 - Indication of crack pattern and global deformation behaviour in all tests
Bottom: Fig 6 – Illustration of the relation between rotation and crack width

tests is schematically drawn.

The results are summarised in Table 1. Green crosses indicate positive influence and a red minus an adverse effect.

Typically, crack widths in the order of magnitude of 1mm are observed in the main cracks, depending on the combination of parameters investigated.

Given the mechanism it is obvious, as shown in Figure 5 and 6, that there is a geometrical relation between the rotation of the roof plane near the rigid connections in the corners and the crack width, and also there is a geometrical relation between the rotation of the roof plane near the supports and the deflection of the roof at mid span.

Therefore the crack width near the corners (or the sum of the crack widths of multiple cracks occur close to each other) must be more or less proportional to the vertical deflection of the roof at mid span. An estimation of this proportional relation can be obtained by assuming that:

- the crack opening is a V-shape, with the maximum opening on the top and zero opening on the bottom of the roof, which means that the corner rotation $\phi = w_{cr}/d_{roof}$
- the deformed shape of the roof is roughly parabolic, which means that the mid span deflection $\varepsilon = \phi \times L_{roof}/4$

With these assumptions

$\varepsilon / w_{cr} = L_{roof}/(4 \times d_{roof})$

When applying this formula on the tested segment 2, with L_{roof} = 1000mm and d_{roof} = 125mm, the ratio $\varepsilon / w_{cr} = 2$. In the fire test

on segment 2, after 26 minutes a crack width of 0.9mm was measured and the vertical deflection of the roof at mid span relative to the connections to the walls was approx. 1.85mm, a ratio of 2.06. This shows that the proportionality of the vertical deflection and the crack width can be well approximated using these formulae.

At the connection with the outer wall, typically two cracks occurred: a horizontal crack in the wall and a vertical crack in the roof. The total rotation in this corner is therefore spread over two cracks. In a full scale tunnel situation, the geometry is somewhat different because the corners are normally designed as a short diagonal part. Therefore the number of cracks near the corner in a real tunnel might not be exactly two, it could also be only one crack or maybe slightly more than two cracks, depending on the exact geometry. If only one crack occurs, it is to be expected that the crack width is larger because all rotation is concentrated in that single crack.

At the connection to the central wall there is one crack, so all rotation is here. The crack above the central wall is typically twice the width of the cracks on the roof corner and the outer wall. This clearly poses a risk to:

- durability of the concrete and especially the reinforcement at the unheated side
- shear resistance of the cross sections near the roof/wall connections

Although this may not lead to loss of structural integrity during fire, it may do after the fire. The test results suggest the following two main conclusions:

- the application of fire protection is an adequate means to limit and control crack width and number of cracks, as well as deflections;
- adding PP-fibres does not contribute to reduction of the deflections, but may have a positive influence on crack widths – the tests performed did not reveal significant differences related to the type of fibres. T&T

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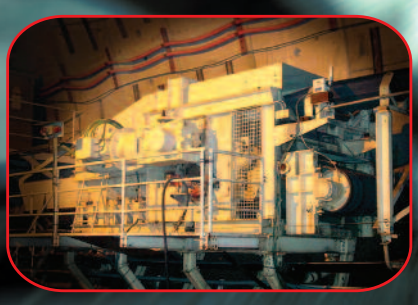

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New metro orders

Fläkt Woods has secured important new contracts to supply tunnel ventilation fans for the latest Delhi and Sao Paulo metro schemes.

This contract for Delhi Phase II follows on from an earlier order to supply the ventilation requirements on the City's metro system. Phase II comprises 128km of route length and 79 stations, and is presently under construction, with the first section opened in June 2008 and a target completion date of 2010.

Fläkt Woods high performance Jet Thrust fans and their axial JM aerofoil fans (including motor protection IP 55 with adjustable pitch impellers) are providing the air movement solution, being used for smoke extract ventilation, as well as for general ventilation of the station concourses.

Purpose designed unidirectional fans are ideally suited for the longitudinal ventilation of metros. The fans have had performance enhancing installation devices to increase installed efficiency, and range in diameter from 1250mm to 2000mm, all are certified for a one off emergency use at 250°C/2 hours.

Sao Paulo metro began operations in 1974 and is a relatively small system with 61.3km of track, carrying 3,300,000 passengers a day. Line 4 is currently under construction and is due to start operating in 2010.

Fläkt Wood's contract is part of the US$5bn capital improvement program that will see construction of two new suburban lines and extension and modernization of three existing lines. The Company is supplying longitudinal JM fans ranging in diameter from 1800m to 2240mm, and massive 2500 vertical mounted JM's.

All fans are tested to the latest internationally recognised standard IS05801 Part 1 (1997), installation category D (AMCA approved) for aerodynamic performance and BS848 Part 2 (1985) for acoustic performance. Coupled with the above fan diameters, the adjustable pitch Aerofoil impeller gives the exact performance required, with a non-overloading fan characteristic.

Fläkt Woods Limited
Web: www.flaktwoods.com

Bearing up

Kingsbury Inc., the inventor and manufacturer of tilting-pad fluid-film bearings, is pleased to announce that the Company has broken ground on an expansion project at its Philadelphia, PA plant to accommodate very large turning machinery and a custom induction heat treating system. This new equipment will allow the company's Messinger Bearings brand to fabricate and repair rolling element bearings up to 25 feet in diameter, the largest size capacity of any U.S. bearing manufacturer. For certain industries that utilize these giant bearings, such as tunnel boring equipment, slewing rings in the steel industry, stacker / reclaimers, off-shore cranes and others, Messinger will be able to provide much faster lead times than were previously available from foreign providers, for both new bearings and repairs.

Kingsbury Inc
Web: www.kingsbury.com

The Latest in Tunnel Protection

Waterproofing manufacturer, Stirling Lloyd Polychem, has recently released its latest brochure, specifically focused on the tunnel industry. Covering various designs of tunnel construction including immersed tube, cut and cover and bored as well as suspended decks in tunnels, the company provides effective waterproofing for the whole industry. The brochure introduces the 'Five Fundamentals of Effective Waterproofing' – Consistency, Control, Suitability, Seamless and Proof – an approach that Stirling Lloyd have been successfully using in the tunnel environment since 1989.

Consistency – On site batching can lead to products variation, potentially affecting the integrity of a waterproofing membrane, allowing water penetration. Stirling Lloyd eliminates the risk of product variation by delivering the material to site pre-batched

Control – A product's full potential is only fully realised if applied correctly. Consequently Stirling Lloyd insists that the installation of their membranes is only carried out by fully training and authorised contractors. This is backed up by a unique on-site quality assurance program.

Suitability – Different tunnel designs have different challenges and therefore the products used should address these unique issues; understanding this has enabled Stirling Lloyd to develop a range of products, each suited to a specific tunnel construction method.

Seamless – Weak joints, especially at complex detailing, pose the greatest threat to the protection of a tunnel. Stirling Lloyd offer spray-applied waterproofing membranes giving a seamless finish with no vulnerable, weak laps and so helps ensure that the waterproofing will be 100% effective.

Proof – A tunnel is a highly valuable asset and performing any necessary maintenance work to the waterproofing is often difficult, disruptive and very costly. The integrity of the membrane should be proved once in situ. One of several quality assurances, Stirling Lloyd's waterproofing systems are electrically tested once cured to confirm the membrane's integrity.

Along with the market leading Eliminator system for suspended decks and the Integritank waterproofing solution for immersed tube and cut and cover tunnels, the brochure introduces their latest membrane, Integritank HF which was launched at the Rapid Excavation Tunnelling Conference in Las Vegas in June.

Integritank HF, which has been eight years in development, has been designed to remove the uncertainty out of the lining of NATM/SCL tunnels. A strong bond to the primary concrete, robust enough to withstand the sprayed application of the secondary lining and a unique lasting quality assurance/integrity testing regime all contribute to allow engineers to know that they have a solution to the problem of waterproofing bored tunnels.

Stirling Lloyd
Web: www.stirlinglloyd.com

Obituary

Obituary – Tom King

For the readers of *T&TI* who knew him, the death of Tom King on 13th June 2009, some weeks before his 80th birthday, came as a great shock. Over the years Tom was the BTS's linkman with the coal mining industry and a member of the BTS Tunnels and Tunnelling Editorial Advisory Board since 1979. His knowledge of the mining industry was of huge value particularly when coal mining flourished in Britain, and his down to earth comments relating to mining and tunnelling were much valued.

Thomas Ignatius King was born in Dublin on 28th July 1929 and grew up with his family in Oldham, Lancashire where he attended Corpus Christie School and Oldham Technology College. He started his career in mining at Moston Colliery, Manchester in 1943 before being awarded a National Coal Board (NCB) scholarship for the BSc Mining Course at King's College, Durham. Graduating in 1951 he obtained his Colliery Manager's Certificate the following year. After working at Bradford and Mosley Common Collieries as a junior official he moved to the No5 Area, East Midlands as mechanisation engineer. He became under manager at Stanley and Coppice Collieries. On becoming Chartered he was appointed, aged 27, general manager of Baddesley Mine, Warwickshire - then the youngest NCB colliery manager in the UK. He was appointed General Manager at Coventry Colliery in 1960 and at Daw Mill in 1971.

In 1976 he was appointed Chief Tunnelling Engineer at NCB Headquarters, Doncaster and later went on to become Head of Engineering (R&D) Division Bretby. The 1970's were exciting times for the NCB and Tom was in the thick of them. He introduced innovative management techniques and promoted mechanization, in particular roadheaders and tunnel machines. He also spent considerable time organizing conferences and presenting technical papers both in the UK and overseas. He retired in 1985 and continued to undertake private consultancy work within the mining industry.

Tom became a student of the Institution of Mining Engineers in 1947, elected a fellow in 1962 and was a Past President of the South Staffs and South Midlands Branch. Considered a 'tracksuit' manager who led from the front he was approachable, motivational and an inspiration. Indeed he could be classed as one of nature's true gentlemen. As well as his professional activities Tom was very involved with a number of charities and was proud to become a Knight of the Sovereign Order of Saint John of Jerusalem.

He was an energetic, kind and humorous and will be sadly missed by friends and colleagues, but particularly by Joyce, his wife of 55 years and their children, Paul, Jonathan and Helen and their families.

Letters

Dear Sir

I refer to Pierre Rossi's article in July's issue of *T&TI* "Steel fibres or synthetic fibres?". The change to macro synthetic fibres in tunnelling and underground construction has grown significantly in the past 5 years as their advantages have become more apparent.

Firstly it is important that the difference between synthetic fibres is well understood. There are two types; macro synthetic fibre and micro fibre, both do different jobs and have different technical characteristics. In the most part when we make a comparison with steel fibre it is the macro synthetic fibre that is the comparable product. These different fibre types are clearly outlined in BS EN 14889 Part 1 Steel fibres and Part 2 Synthetic fibres.

Generally, the way in which fibres have been specified in underground construction is to achieve a specified energy absorption either in a plate test with a corresponding Joules performance or a beam test with a corresponding Re3 value. This enables the designer to verify that the specification is being achieved and the contractor to choose the most economic fibre solution.

BS EN 14889 prescribes a beam test to do this. Dramix 65/35 achieved the required performance with 25kgs/m^3 whereas Barchip Shogun used 5kgs/m^3. These figures are nominated on the resulting CE certificate. Users must then weigh up the costs and advantages of using one fibre over another.

The writer describes creep. The first step is to decide whether creep is relevant. This may not be the case in underground construction, as either the FRS is placed as a temporary primary lining and/or the loads are of a compressive nature such as a precast segmental lining. Current research shows that fibre reinforced concretes may creep but well within the limits for long term loading. How much the FRS creeps will depend on the type and amount of fibre used and the loading size. If creep is an issue, designers must provide guidance on testing and performance criteria.

Although the writer suggests that durability is not an issue for steel fibre there is clear evidence (Bernard, Hagelia) that steel fibre suffers significant corrosion and therefore performance loss at crack widths larger than 0.1mm after only a few months. This is not the case for macro synthetic fibre. Using a galvanised fibre is not only very expensive but unnecessary. The most recent research suggests that the "embrittlement" of concrete causes significant performance loss in steel fibre reinforced concrete. This is apparent in concretes older than 56 days where the energy absorption in a plate or beam test much reduces due to the brittle nature of the concrete, particularly in concrete over 40MPa. This is of great concern as most infrastructure projects demand lifespans of 50 years +.

As with steel fibres there are a wide variety of macro synthetic fibres on the market with varying characteristics and quality. Constructors need to examine these technical characteristics closely and I suggest that for underground construction only macro synthetic fibres with the relevant conformance to BS EN 14889 Part 2, a minimum tensile strength of 500MPa and a Young's Modulus greater than 8GPa be used as this determines both short term and long term performance.

Macro synthetic fibre is replacing steel fibre in tunnelling faster than ever before as engineers gain confidence from the increasing numbers of tunnels completed using synthetic fibres and the advantages they offer both technically and logistically. Users can also gain confidence from the fact that the steel fibre producers themselves are now promoting their own synthetic fibres in the market place.

Andrew Ridout
Elasto Plastic Concrete (Europe) Ltd

The belt storage at the Aica / Aicha-Mules / Mauls tunnel portal.

Belt conveyor at Brenner preparatory works

Rock haulage at the 10.4 km exploration tunnel and access adit to the future Brenner base tunnel between Aica/Aicha and Mules/Mauls in Upper Isarco valley in South Tyrol, Italy is performed by means of a new conveyor belt designed, built, supplied and commissioned at the site by Marti Technik.

The 800 mm wide conveyor belt in the 6.3 m (31 m^2) OD, 5.6 m ID tunnel will follow curves with radius of 400 m, 500 m and 1,200 m. The conveyor has capacity for 450 t/hour to haul 304,500 tonnes altogether. It is powered by 800 kW and driven by two boosters.

During the drilling process with a TBM, precious geological and hydrogeological information is collected and analysed. This knowledge will facilitate the construction of the main 55 km tunnel by reducing the risks in terms of budget and schedule.

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APGUS review

Helen Nattrass, the British Tunnelling Society's Chairman of Lobby Group for the All Party Parliamentary Group for Underground Space Tunnellers and Politicians, presents this review of the last year

The All Party Parliamentary Group for Underground Space (APGUS) has had a successful and interesting season over the last Parliamentary year. Founded in 2002, APGUS has slowly gained increasing interest and more core Members in the Houses of Parliament. Looking back over the year's activities, Parliamentarians have attended a visit to the Croydon Cable Tunnels, a visit to the Hindhead road tunnels, a presentation on Carbon Capture and a visit to the Brunel Thames Tunnel. APGUS Chairman, the Rt. Hon. Nick Raynsford MP, is very much in evidence on these occasions, and is always accompanied by other Parliamentarians from both the House of Commons and the House of Lords and across the political spectrum.

Aims and objectives

APGUS aims to inform politicians about the planning, design and construction of underground structures. A site visit gives them an unparalleled opportunity to hear about such matters directly from those involved, with no filters applied. It allows them to see for themselves our underground works, which are, by their very nature, hidden from public view. Nothing is more exciting for those accustomed to the plush carpets of the 'corridor of power', than to get on a pair of overalls, hear a safety talk including scary instructions for a 'self-rescuer' and get down to the tunnel face. (On a previous visit after the self-rescuer instruction, a Peer of the Realm was heard to mutter with gleeful anticipation, 'What a way to go!')

Our activities over the past year have allowed a number of Clients, Designers and Contractors to show-case their work and to lobby directly on matters which are of concern, both locally and industry-wide.

Our visit to the Croydon Cable Tunnels was hosted by National Grid and Morgan Est. National Grid had an opportunity to talk about the cost-effectiveness of putting power cables in tunnels, and to explore the economics of extending this initiative to other UK regions. Morgan Est were able to explain how they went about constructing the tunnels and review how tunnelling machines can encounter variable and unexpected conditions. The site installation and urban setting of the project was also of considerable interest to the group.

Our visit to the Hindhead Tunnels was an auspicious occasion for BTS Chairman Paul Hoyland to welcome a group from APGUS to his own project. The Highways Agency and Balfour Beatty gave short presentations about the project background and the current construction methods. It is not every visit where the Parliamentarians actually get right to the tunnel face. But they did at Hindhead. They had the opportunity to view at close quarters a roadheader cutting the face in one tunnel and a shotcrete robot at work spraying in the adjacent tunnel. Everyone wanted a copy of the photograph showing them at the tunnel face.

Early in 2009, we were asked to arrange a talk about Carbon Capture. This was, and continues to be, a subject exercising many Parliamentarians. Our speaker Ian Phillips of 'CO2 DeepStore' gave a masterly account of environmental trends, climate change, predictions of future energy needs and future energy resources. Hailing originally from the oil industry, Ian's company is working to deliver the practical transportation and storage aspects of Carbon Capture. Ian spoke of the need to transfer energy-generation away from fossil fuels which creates large quantities of greenhouse gas. He likened Carbon Capture to a sort of 'sticking plaster' to help in what he viewed as the inevitable the transition. The talk was very well attended and attracted a number of Parliamentarians who had never before been to an APGUS event.

Our most recent outing, the visit to Brunel's Thames Tunnel, was possible due to the current East London Line upgrade works; allowing a visit during normal working hours! This time Transport for London and Balfour Beatty-Carillion JV were our hosts. Our visit began in the Brunel Museum with Director Robert Hulse recounting how Brunel's Thames Tunnel was built and recalling its many uses before it became the conduit under the River Thames for the East London Line. The ensuing site visit was a unique opportunity to view a structure of historic importance which is still in current use. Seeing Brunel's own work, albeit slightly obscured by modern rendering or shotcrete, was a really exciting moment. It precipitated some pointed discussion about the real meaning of sustainability!

Above: **The APGUS group visits the A3 Hindhead Tunnel project**

Spreading the message

Engineers have never been strong at attracting attention to their achievements; tunnellers being no exception. It is fundamentally important that those who shape and enact Government policies are well informed about the tunnelling sector; who we are, what we can do and how well we do it. APGUS is supported by the BTS so that ordinary Parliamentarians can have access to examples of our great works. Supplemented by the talks and presentations we arrange, the APGUS Parliamentary Members are subtly educated and gain impressive first-hand experiences and knowledge which we hope they will use to support proposals for underground structures and projects for tunnellers in the future. T&T

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Looking back at Hindhead

At the May meeting of the British Tunnelling Society, Roger Bridge, Balfour Beatty, Paul Arnold, Highways Agency and Simon Stephenson, Mott MacDonald described construction of the UK's Hindhead Tunnel

The Devil's Punchbowl stretch of the A3 was identified as requiring serious improvement works in 1983. Route consultations were undertaken before the scheme entered TPI in 2001. In 2002 the contract was awarded to Balfour Beatty, with the issue of draft legal orders and the Environmental Statement awarded in 2003. This fed into the Public Enquiry in 2004 before being delayed further whilst the decision to proceed was made. This was finally granted in October 2006 with work starting on site in January 2007.

The A3 is a trunk road, owned by the Highways Agency (HA) who employed Atkins as their Agent on the scheme. Balfour Beatty employed Mott MacDonald as their Designers. Halcrow were subsequently given the task of category III checker.

The existing A3 reduces from dual to single carriageway as it heads south just before reaching the Devil's Punchbowl feature. The aim of the scheme is to divert through traffic away from the congested traffic lights at Hindhead and make the new section of road dual carriageway (figure 1).

Procurement strategy

The HA chose the Early Contractor Involvement Model using ECC Option C Target Cost. A number of significant benefits were derived from this not limited to the fact that the design for the draft orders and the environmental statement was developed to reflect the most cost effective option. This option made the contractor accountable at the public Enquiry and enabled a "flying" start once the public enquiry was completed.

The tenders were based on works and site information and the bidders submitted a quality submission, staff rates for Phase 1 and a target price for Phase 2 works. The contract made the Contractor responsible for ground condition risks, and weather risks.

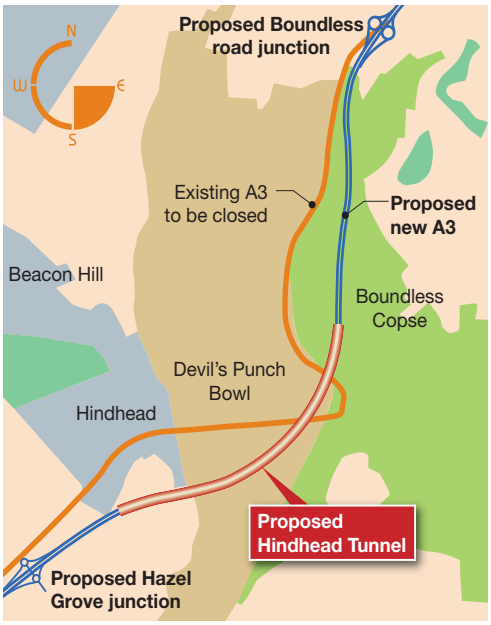
The contract adopted ECC Option N inflation clauses using the Baxter Indices for Civil works and BEAMA for Mechanical & Electrical items. At the end of Phase 1A the target cost was re-assessed and forecast savings from the Value Engineering process were shared. A pain/gain mechanism is included in the contract for the eventual division of any deviation from the target cost.

Design

The scheme comprises twin 1.8km dual lane running tunnels with 16 cross passages.

The geology comprises weak sandstone interbedded with sand layers (figure 2). The sand percentage increases in the upper strata and so an alignment constraint was the need to try to dive quickly into the better material. Clay is present in lower strata and the water table is found on top of the impermeable clay layers. The alignment was selected to keep above the water table as the material is highly degraded by the presence of water. The final alignment requirement was to keep adequate cover to the surface.

Structurally, the primary lining provides the permanent load bearing structural lining. A waterproofing membrane is placed on the intrados of the primary lining and the sacrificial secondary lining is placed against the waterproofing. The secondary lining



Above: **Fig 1 - Plan map of the alignment**

QUESTIONS AND ANSWERS

Question 1 - Hadyn Davis - London and Continental Railways.

How did the project confirm the permeability of concrete to meet the specification requirement of $1x10^{-12}$?

Simon advised that the test method used was to BS EN12390 Part 8. The sample was placed under water pressure for 7 days. The sample was then split and the water penetration was checked to be less than 50mm.

Question 2 - John Scholey - Jacobs

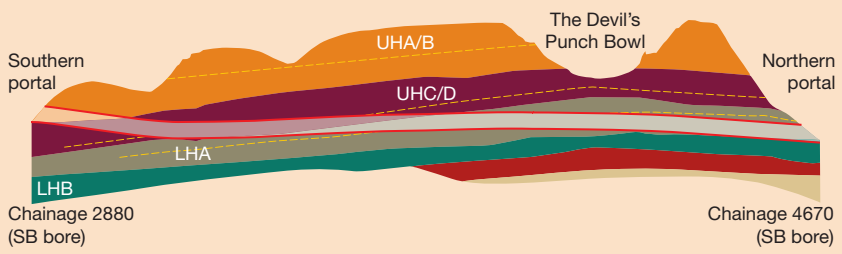
It was observed that the crown of the tunnel was sprayed to infill the "saw tooth" effect from the use of spiles. Did the project team consider the value engineering opportunity to leave the crown untreated?

Roger Bridge responded that the ventilation design was driven by the roughness of the tunnel and this had been the controlling design parameter.

Q3 – Parinampalam Linkeshwaran

The speakers described the balance of labour cost vs. mechanisation in the development of methods of construction. What other techniques were considered and how did the balance compare to the selected methods.

Roger Bridge advised that a single option evolved using the balance of labour cost vs. mechanisation. However this was now over 4 years ago.



Above: Simplified longitudinal section

consists of cast mass concrete walls and an unreinforced sprayed crown, both featuring polypropylene fibres for fire resistance.

The primary lining is 200mm thick unreinforced sprayed concrete. With the exception of fibres, it includes no steel and so is considered durable, providing the structural support throughout the lifetime of the tunnel. The lining is excavated in two stages, a full semi-circular heading and a bench. The geometric layout of the design means that no tensile forces are generated in the lining. This allows the design to assume plain concrete (no account of the fibres is taken in the design). Both excavation stages are supported on 'elephant's feet' which transfer the load in the lining into the ground.

A 'design menu' was presented to the Contractor at the start of construction. Six excavation and support types and eight additional measures were provided so the optimum support level was installed at all times. The support types ranged from the base case of full-face heading and bench with advance lengths of up to 2m (in competent rock) to the worst case of canopy tubes and full-closed inverts with advance lengths of 1m (in sand-dominated strata).

Additional measures described included canopy support measures, face support measures and structural inverts. These were occasionally specified at mandatory locations but were mainly designed to be installed in response to tunnel monitoring and geological mapping information (figure 3).

Construction

Tunnel face excavation undertaken using a Liebherr 944C tunnel spec machine of suitable size and capacity to undertake the works whilst ensuring the latest engine conforming to the European Off Road Tier 3 Emission Standard was adopted. This logic also applied to the Liebherr 566 loading shovels. The bench excavator chosen was a Terrex ITC Schaeff 210 electric version.

The excavators were sourced with ripper buckets for the bulk of excavation activities with transverse cutter and breaker attachments available, shared between the three heading excavators and similar for the two Schaeff excavators, the second of which was used for cross passage excavation. The bucket solution was adopted as the main excavation tool to minimise dust generation.

Originally the programme had planned to see the northbound heading advance and the bench start approximately 150m behind following by the southbound heading and then the southbound bench.

The critical path for the project was to ensure the breakthrough of the northbound tunnel in time for the 2009 earthmoving season to enable 400,000m^3 of excavated material to be transported through the tunnel from the 22m deep cutting at the south end of the scheme at the Hazel Grove junction and place it in the embankment to be formed in the boundless valley.

The conveyor located within the tunnel is the perfect mechanism for the completion of this activity, with early high quantities being catered for by the additional use of 8 x 30t ADTs. For these activities to take place only the heading was required to have been completed, providing an early access route.

The tunnel works programme required the southbound bore to be completed to its final profile to enable secondary lining works to progress. With these constraints leading the logic for phasing of the drives it was decided that the project team would lead with the northbound heading closely followed by the southbound heading and then the southbound bench. Daily checks were undertaken to ensure that a minimum gap of 25m between faces was maintained to prevent destabilisation associated with loads from other excavation faces.

The northbound bench only advanced when it suited work in the southbound bore. This unrestricted access provided a safe route through for emergency services and tunnels personnel without having to pass an operational face. As the benches were not being advanced simultaneously, the cross passages could not be excavated. For safety reasons it was decided to construct steel framed man access passages in the envelope of alternate cross passages ensuring a route to a safe environment within 200m of the heading faces.

The geology of the tunnelling horizon is a well known feature named the Hythe Beds, overlying the Atherfield clay bed.

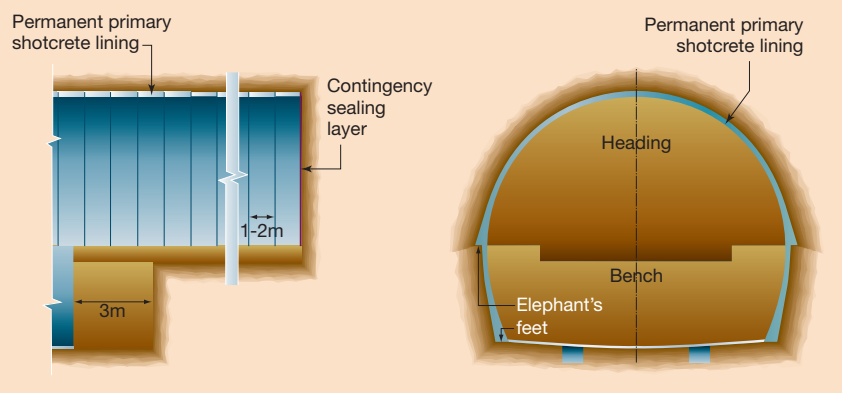
Present amongst the beds are three tracer beds on montmarilionite that have acted as tracer beds during the Site Investigation.

This model was found to be inaccurate at the north portal when portal excavation work discovered a discontinuity determined to be associated with a graben feature. The punchbowl Hythe beds are an anticline and the dome has suffered tension cracking and subsequent filling with poorer material from above. In total 4 graben features – 8 fault features were encountered. One of these pairs was in the portal for the northbound heading and all were encountered in the southbound bore. Early in the development of the tunnel system they were handled with great care and the team eventually passed through this zone of disturbance without significant issue to the credit of all involved.

Design review

The tunnels team held a design review meeting daily. The designer chaired the meeting attended by the Contractor and Atkins (in the role of independent tunnel engineer) and reviewed all data relevant to the tunnel, settlement, in tunnel deformation, geology, shotcrete profiles and quality. The outcome was a Required Excavation and

Below: Fig 3 - heading and bench excavation, and use of SCL



Support Sheet (RESS), which acted as a permit to dig the tunnel. Without a current, signed RESS, no excavation was permitted.

The key factor for control of the crown stability was the variation of advance length with upper limit being set in the RESS but the site team having the option to reduce advance lengths, should prevailing ground conditions indicate it necessary.

This process provided a daily review of the status of the tunnel works and looked at the new data in comparison with trigger values and limits as well as reviewing trend data in an attempt to predict any problems and ensure suitable mitigation was in place.

Early in the development of the scheme during the plant selection process, the goal of developing a profile control system that linking the excavator and the spraying operations was seen as an integral part of progressing productivity, quality and safety. The system would ensure that no personnel would be required to enter areas of exposed ground to check profiles, excavation cycles would be more efficient with less over or under break, and the profile of the applied primary lining would be improved.

A number of suppliers were involved before the decision was made to adopt the solution proposed by VMT, AMBERG and BASF. The three companies worked together to develop a system that would permit the operator of the excavator to have a display in their cab showing the excavation profile against the theoretical profile for that advance. Additionally the system was designed to allow a record of the excavated profile to be transferred into the network in the project offices for review and archiving. In conjunction with this the connection of the Logica Potenza spray robot into the system meant that the scanning facility of the Logica could be coordinated to enable the sprayed profile to be compared with theoretical.

Due to problems associated with positioning and tracking the machines, the system is undergoing development. The control of excavation and shotcreting was completed using reflectorless techniques.

With the performance specification for the primary lining shotcrete requiring an early strength of 1MPa at 1hour, trials were unsuccessful at achieving this figure with a number of mix variations. Extensive testing was undertaken with the Hilti penetration and pull out tests using the standard calibration curves for penetration and pull out force against associated strength.

The testing regime was revised to include comparative testing of cube compressive strength in parallel with the nail testing on an identical cube. This identified the standard curve to be non representative for the mix proposed. It was considered that this was likely to be linked to the aggregate size.

Above: **Steel pipe canopy installation at weakest south end of bores**

The Sandvik Tamrock Axera 8 drill rigs have three possible options for the flushing of drill holes. Air flush, water flush or air/mist flush. Due to the high silica content of the ground being excavated, the use of an air flush system would have generated unacceptable quantities of airborne respirable crystalline silica dust, likely to exceed the revised eight hour time weighted average limit of 0.1mg/m^3. The water flush system uses approximately 30 litres/minute to ensure the drill string and hole remain clear. Due to the silt content and the nature of the ground there were issues associated with hole stability and the surrounding ground as well and logistical concerns over the handling of these quantities of water that made this option undesirable. The adoption of the air/water mists system was the obvious alternative to adopt and reduced the water consumption to 10 litres/minute whilst ensuring that there was no dust generated and the stability of the ground being drilled was retained as well as possible.

A feeder/sizer unit was installed at the front end of each conveyor allowing the loading shovels to tip into the hopper of the feeder (a chain conveyor) and not directly onto the belt which would cause stalling or tearing. The chain conveyor in turn tipped into the sizer unit. This served two purposes, firstly it reduced the excavated material to a size that would ensure it did not damage the belt and secondly the size was selected to meet the grading requirements for the structural backfill in the embankment at the north portal (150mm down). The belt was 900mm wide with the capacity to transfer up to 400 t/hr.

Due to the nature of the Sandstone and it's high silica content, there were concerns over the exposure limits set for respirable crystalline silica dust. Part of the mitigation for this was the sourcing of de-dust units. Each tunnel had the overall capacity to treat 50m^3/second. This was achieved by the selection of 2 number 25m^3/second CFT dry filter units. The units are self-cleaning and proved to be a reliable and effective solution to dust control. The majority of sampling undertaken during the excavation and spraying of the tunnel showed RCS levels less that the targeted 0.1mg/m^3 (8hr TWA).

Production achievements:

- North Portal Headings; 30m stagger for face stability, working 24/7 – Two shifts/ three gangs - up to 50m/week each heading
- South Portal Headings; both faces working – excavation/support, working Monday to Saturday – days only, up to 9m/week each heading including pipe canopies
- All benches; achieved average of 80m/week per face

At breakthrough the closure between the north and south portal drives was less than 20mm horizontally and 5mm vertically.

Summary of achievements

At the presentation the tunnel had achieved breakthrough of both headings (northbound 3 weeks early), (southbound 10 weeks early, early start contributed) and completion of both benches. Excavation of all cross passages was finished including low point sump passage and shaft whilst the invert drainage and slab works were advanced. T&T

Tunnelling Procurement

Iain Suttie, associate in Berwin Leighton Paisner LLP's Construction, Engineering & Procurement Group, describes the legal aspects of tunnelling procurement

Major engineering contracts are fundamentally mechanisms for allocating risk and reward, and the choice of mechanism to be used is now wider than ever. The ways in which tunnelling projects are procured have developed hugely in recent years, both in the United Kingdom and internationally. Clients now have an array of possible contracting strategies and funding options that were, until the 1990s, unknown or largely untested.

This has led to greater complexity in the forms of contract used - even where they are based on standard forms. Major clients are likely to deploy routinely a mixture of techniques, such as partnering, alliancing, framework agreements, performance metrics and risk-reward sharing devices in relation to tunnelling projects. At one time it was usual for procurement to be split sequentially into design, tender and construction phases with a relatively straightforward payment mechanism, typically incorporating rates and remeasurement. The position now is one of marked and increasing sophistication, as project learning is fed back into the procurement process.

So it is difficult to generalise about which particular method of procurement should be adopted for a tunnelling project. Moreover, some of what has become received wisdom over the last decade may now be under challenge. Some major clients, for example BAA, have recently stated that they will move away from established partnering arrangements and will now only award major contracts through full open-market tendering.

But in this, the first in a new series of articles broadly dealing with contractual issues and dispute avoidance strategy, we will draw on recent practical experience to highlight some features of successful tunnelling projects, and their procurement, that we have been involved in. Topics that we touch on, such as ground risk, allocation of design responsibility, change management and risk registers will be more fully addressed in future articles.

Client mobilisation

At the highest level, the procurement of many major tunnelling projects will be driven by factors such as governmental policy or the need to comply with regulatory developments (for example, in the water industry). Often, important parameters of the required tunnel will not be fixed or fixable at project inception and a variety of procurement solutions may be possible.

In our experience, the need for a client organisation to articulate and analyse key project drivers and constraints at the earliest stage is a key element of successful projects. This may sound obvious, but it is worth emphasising, not least because the process of initial, internal project appraisal and interrogation is a distinct "project" in itself and requires a high degree of internal client engagement. Such an exercise will identify both known constraints and "known unknowns", such as possible engineering challenges or the availability of funding which may depend on approval from external regulators (as is commonly the case in the UK and US).

A clear, early and honest appreciation of issues that may or may not arise or which may require to be resolved in one of a number of ways should lead to an appropriate degree of flexibility being built into the procurement mechanism and the actual contracts awarded.

Many of these issues will relate to design and funding. Other issues likely to require detailed consideration at an early stage include engagement with and management of stakeholder interfaces and how to build flexibility into procurement processes that must nevertheless comply with any regulatory constraints (e.g. the EU utilities procurement rules).

An example of a project where such constraints would be obvious is a major urban railway station upgrade, perhaps with funding from various sources, involving new

shafts and tunnels and linked to the construction of an adjoining retail development. The client would have to articulate and make clear to its team key project constraints and milestones (including those set by the developer's works), so that all parties are aware of critical dates and third party requirements.

The initial analysis will also identify the client's ability to resource the management and design of the project. This may lead to an early decision being taken to appoint an external programme manager and other delivery partners. Careful thought needs to be given to the scope of their appointments and how they will engage with contractors, bearing in mind that the procurement process for contractors is unlikely at this time to have been fully resolved in relation to the construction phase.

As a minimum, one would hope that by the end of this initial phase the client has been able to develop a clear strategic view of the main regulatory, technical and legal risks and constraints, as well as stakeholder requirements, and to have made a cultural commitment to its delivery strategy.

Contractor engagement

The detailed choice of procurement route, relating to the terms on which a contractor is selected and engaged, will fundamentally depend on the degree of project risk a client wishes the contractor to bear. The degree of risk transfer will largely be determined by cost factors, which in turn will be influenced by programme constraints and the technical feasibility of a contractor taking on and managing specific risks.

As the initial analysis is developed during the procurement process, a client may decide that there are major project risks that it definitely wishes to retain, for example in relation to design. This may be due to a wish to maintain close control over the quality of a particular element of the project or so as to invite more competitive tenders, with some risk premiums stripped out. Where such risk sits ought to influence the level of any target cost, which may in turn impact on the degree of incentive for the contractor to engage in value engineering.

There are a number of obvious key areas that may be considered when scoping risk, so that it can be allocated appropriately to achieve a greater degree of cost certainty or, at least, transparency.

First, promoting early contractor involvement. This is typically achieved through a two-stage contract process, allowing a contractor or contractors to be brought on board at a relatively early stage of the design, where the greatest benefit may be derived from their experience. Early contractor involvement in principle minimises design risk and may also have programme benefits.

But early involvement is not a panacea. If a contractor is brought on board before pricing parameters are significantly developed, the client may find that there is a marked loss of competitive tension. The issue is compounded by the practical difficulty of not continuing with a contractor selected at first stage.

Crossrail's Optimised Contractor Involvement method is an attempt to square this circle. The focus of this method is to involve contractors at a stage where design is sufficiently advanced to allow for a high degree of overall cost certainty, but while there is still scope for the contractors to deliver significant added value. It may be that under this model the benefits delivered by contractor involvement will result not from significant design re-evaluation, but from improved methods of working and logistics (for example in relation to choice of tunnelling technique, selection of the TBM or the design of temporary works and structures). Whilst this approach has clear advantages for a client, it must consider what assurances to give the contractor on the use of commercially sensitive information relating to working methods should a different contractor be appointed for the construction stage.

Second, a clear approach to the identification and allocation of risk relating to unexpected ground conditions. This is perhaps the single biggest cost risk on any project. Contractors will not absorb this risk without a price premium. So it may well be necessary for considerable potential risk to remain with the client. This may be appropriate. There are, however, strategies for enhancing cost certainty and reducing the likelihood of claims in relation to ground risks.

One approach that we have seen is for the tender process to require the client and contractor to agree and define normal or expected ground conditions. Conditions falling within the mean will not of themselves give rise to claims. This will be explored further in a future article. It can be said that the need for such an approach is inherent in projects using NEC's Engineering and Construction Contract, given the particular wording of the relevant compensation event.

Third, the development and incorporation into the contract of processes for actively identifying and managing risks as they occur. This is a key feature of the culture of successful projects and is realised through mechanisms such as risk registers and early warning systems.

One issue that we have seen on occasion is an attempt to use the risk register as a means for not only identifying risk, but also allocating it. This approach is antithetical to the proper use of risk registers and is likely to undermine the culture of openness and co-operation that they are supposed to encourage. Ownership of and liability for risk should always be determined in principle by the contract conditions - which means that such issues need to be bottomed out at tender stage.

Fourth, the establishment of a change management system that allows for design and programming changes to be agreed and implemented efficiently. All standard forms of contract have more or less sophisticated procedures for managing the cost and time consequences of changes. But these need to be analysed for their suitability, so as to ensure that they reflect the risk allocation desired at commercial or project level.

Moreover, there will be a great many changes on a major project. In particular, tunnelling contracts require the flexibility to deal with changes enforced by third parties whose assets may be affected by the works, as well as design and working methods that can be adapted to deal with unforeseen ground or structural movements. The requirement to deal with change in an efficient manner unhindered by unduly arduous contractual requirements is essential to minimising programme and cost impact. This is particularly the case in urban tunnelling schemes, where the need for third party approvals, for example from railway operators and bodies such as English Heritage, often results in changes.

A question to ask is whether all changes require to be dealt with in the same way. If upfront management and pricing of change is key, are there ways to streamline the process? Clearly, procedures and time limits are important, but should not become ends in themselves.

The choice of contract price mechanism will reflect and underscore the approach chosen to risk management and sharing. Target cost contracts, at least in the UK, have become quite standard, as, in theory at least, they motivate the parties to work closely together to address risk. But that is far from saying that target cost options will always be the correct price mechanism for a project.

Forms of contract

Finally, some thoughts on the selection and drafting of contract terms. This should, in the run up to a major contract tender, ideally be a reflexive process. The drafting of the detailed terms should reflect the desired risk allocation and management processes, rather than drive them. They also provide an opportunity to interrogate and validate assumptions made about how a project will be delivered. If a standard form of contract is adopted for a project, the form selected should, as closely as practicable, reflect key project parameters, or at least allow for these to be readily encapsulated through bespoke amendments.

Perhaps unsurprisingly, NEC's Engineering and Construction Contract ("ECC") has emerged as the most popular form on which to base tunnelling contracts in the UK. It has been used on projects such as the Channel Tunnel Rail Link and as the basis for the bespoke Terminal 5 agreement and is commonly used by major utility companies and the Highways Agency. Use of the ECC on major projects can largely be attributed to its focus on promoting both co-operation among project participants and active, upfront risk and change management, together with the relative ease with which it can be made project-specific through selection from a range of pricing and other options. Its popularity has been enhanced through government endorsement, awarded to it in recognition of these features.

Indeed, the rise of NEC and its seeming eclipse, at least in the context of major UK projects, of other forms of contract, such as ICE, can be seen as largely driven by the various changes in procurement that we broadly identified at the beginning of this article.

The ECC's flexible nature allows it to be used in connection with a broad range of procurement routes, including those requiring either limited or major contractor design input. Such inherent flexibility means that the detailed works information must be prepared with the utmost care.

Internationally, FIDIC's Red (traditional) and Silver (turnkey) books are likely to be encountered. In terms of general approach, FIDIC is much more orthodox than the ECC in its structure and approach to risk allocation and management.

Conclusion

Ultimately, the success (or failure) of a project will depend less on choice of contract, but on how it is operated and the philosophy and aims that underpin it. These should be the focus of a client's strategic planning - the choice of contract can and should follow.

And when one considers the capacity of repeat clients to procure tunnels in a range of physical and market conditions, there seems little reason in principle for committing to a particular contract form at the earliest stage before the shape of a project has become well defined. T&T

This is the first of a series of articles relating to contractual issues and dispute avoidance strategy in underground construction, produced jointly by Berwin Leighton Paisner LLP and Navigant Consulting (Europe) Ltd.

Optimising sewer investments

Ian Clarke describes a novel method of keeping on top of asset deterioration. (edited from a paper presented by Matt Wheeldon BEng (Hons) CEng MICE, Wessex Water Services Ltd

Understanding the rate that the UK's sewers are deteriorating has been the subject of much expert judgement, strong opinions and statistical modelling based largely on poor and inadequate data. Likewise, knowing where to look to proactively invest the limited monies available to Water Companies before sewers collapse, with the resulting service failures, has generally been 'Consequence' driven rather than 'Risk' driven. In a significant effort to establish a 'Risk' driven approach to the problem, Wessex Water has developed what it claims is an industry leading approach to quantifying the rate of sewer deterioration by utilising time-spaced observed data. It has also sought to optimise its investment by assessing each sewer length using a risk-based approach driven from asset, operational and geospatial data.

Back to basics

The UK's sewers are critical infrastructure, yet little is known about them with only small volumes of proactive maintenance work being carried out on them. All sewers can be said to be 'critical' because failure of any of them will lead to a service failure for customers. However, unlike many other infrastructure assets, there are generally no standbys for sewers.

The length of sewers owned by the UK's 10 water and sewerage companies amount to c323,000km, and this is before any changes in 'private' sewer ownership come into effect in 2011. Latest figures show that the average annual industry sewer rehabilitation rate was just 0.06% of the total sewer network.

The issue here is working out whether this low level of investment is sustainable in the medium to long-term. To answer this question, it is important to understand how quickly such 'long-life infrastructure' is really deteriorating.

The state of the nation's sewer network

Sewer deterioration is a complex process influenced by a number of factors: time, ground movement, third parties, material, surface loading etc. The structural condition of sewers has for many years been assessed using Structural Condition Grades (SCG) 1 to 5 (five being the worst). The reality is that most sewers in this country have not been visually observed since the day they were laid. The pace at which they progress through the SCG's towards a score of 5 is, for most sewers, exceptionally slow - little movement happens from one year to the next. On top of this, national failure rates are still at only c13.5 collapses per 1,000km of pipe network per annum.

This leads to the question 'Is the current level of investment adequate or are we actually storing up a massive nationwide problem for the future?'

To answer this question we have to better understand the deterioration rates of sewers.

Determining sewer deterioration rates

The information that has been missing to help the UK water industry understand this ageing asset base is how quickly sewers progress through the structural condition grades. This can only be reliably obtained by observing the assets using CCTV investigations.

A 2006 study for the UK Water Industry Research group concluded that 'Current CCTV archives provide little useful information in the form of repeat sewer surveys that could be used to track deterioration of condition and develop models that can be used to predict the future condition of the asset stock nationally.'

However, Wessex Water has collected CCTV survey data over many years in a consistent format and recently this extensive dataset, containing repeated CCTV surveys on 10,000 sewer lengths (covering about 600km or 4% of its total sewer asset base), has been analysed.

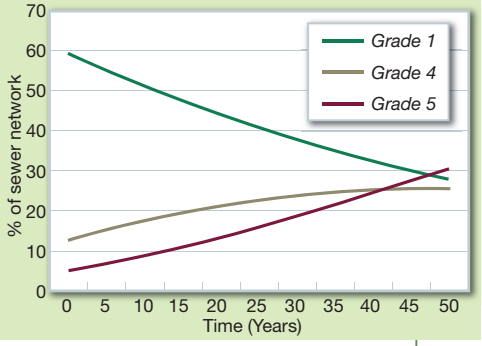
The data collated has been analysed to investigate how sewers have deteriorated over time by observing how SCGs have changed in the time between surveys.

Such matrices, combined with statistical analysis methods have enabled the observation and measurement of sewer deterioration rates. However, like any model, these are only truly valid for the observed part of the sewer network and over the period of time between the surveys. Therefore Wessex Water did not consider it a reliable tool to measure the overall sewer deterioration rates for the whole of its asset base.

To overcome these uncertainties, the approach used two probability matrices derived from CCTV surveys - one from observed data 10 years apart and another with data observed 15 years apart. The datasets were also from different parts of the sewer network across Wessex Water's region.

The two datasets were used to calculate two 30 year deterioration estimates (2x15 year and 3x10 year) which were then compared by performing a Z-value test.

Below: Fig 1 – Predicted movements of SCG of sewers over time



The results showed a 90% statistical significance level indicating that the observed deterioration rates in the two datasets were statistically consistent.

Using this sewer deterioration model based on observed data, it became possible to predict the rate of decline of sewer structural condition and therefore predict what would happen over time to the SCG's of the sewer assets if no proactive investment was undertaken.

Based on the observed deterioration rates, the model predicts that c2% (320km) of Wessex Water's sewers will deteriorate into a condition grade of 5 over the next 5 year period.

From analysis of historical and current rates of renewal it is clear that the level of investment (by the industry as a whole) is not keeping pace with the underlying rate of sewer deterioration. Until renewal rates equate or exceed deterioration rates, it is logical to argue that the long-term stability of these assets is not guaranteed.

Optimising investment using sewer risk scoring

Understanding how quickly sewer assets are deteriorating is crucial for understanding the level of investment required. However, to ensure this investment is optimised regardless of expenditure levels, it is vital to know where any such investment is most needed. Again, this is not straightforward for an unseen and largely unknown asset base which does not yet show significant evidence of major problems.

Current UK industry practice defines sewers as either 'critical' or 'non-critical' depending on the 'consequence' of failure. The standard approach over many years has been a programme of proactive surveys for the 'critical' sewers and, where needed, rehabilitation. This however, left somewhere in the region of 80% of the assets, (the 'non-critical' sewers), to be dealt with as 'reactive only' investigation and investment.

For a risk-based approach to investigation and investment, an assessment of probability of failure needs to be established.

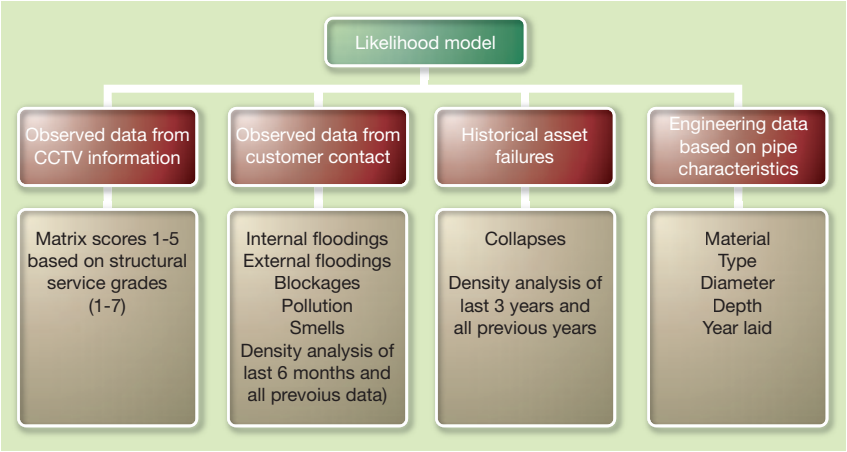
Establishing a 'likelihood' model to predict the probability of failure of a sewer is not easy. As previously mentioned, structural failure of a sewer can be a complex process involving a combination of many different factors. The likelihood of asset failure is closely linked to the SCG, which can only be obtained from CCTV data. The likelihood model used by Wessex Water utilises the SCG as the primary indicator, but since a comprehensive dataset of this information does not exist and would be prohibitively costly to obtain, (cUS$33M for Wessex Water), the model also uses supplementary indicators such as operational and sewer characteristics, which also contribute to the probability of each sewer length failing (figure 2).

The model uses a 'dynamic weighted' approach to compensate the problem of not having a comprehensive coverage of all desired asset information (Table 1).

Density analysis is performed and presented geospatially for operational and asset failure information. This information contributes to the overall 'likelihood' score in the assessment process, examples of which are shown in the accompanying figures 4 & 5 (p37).

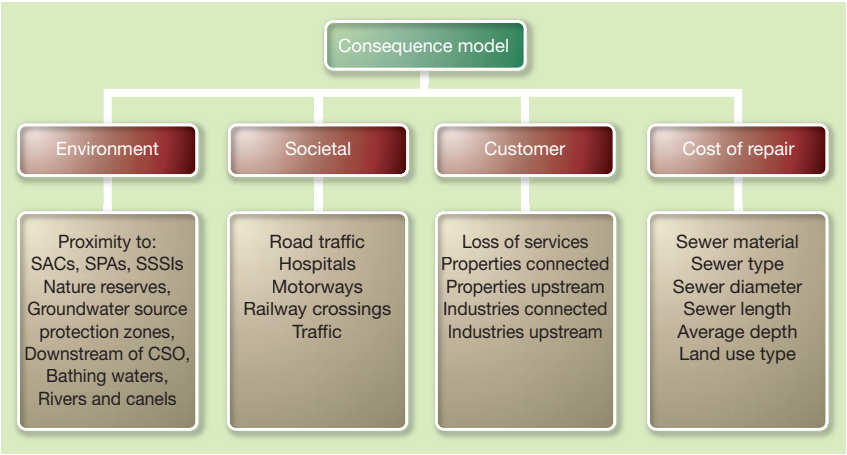
Alongside the 'likelihood' model this approach also requires the establishment of a 'consequence' model. In this instance, identifying, assessing and scoring the consequence of a sewer failure has utilised information abstracted from Wessex Water's corporate Geographical Information System. Using a similar process to the 'likelihood' model, a 'consequence' score is calculated for each sewer length (figure 3).

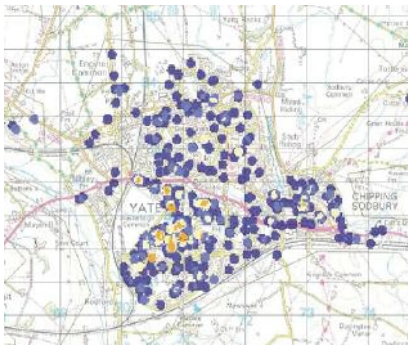
This then allows the company to apply a risk-scoring process to its investment strategy. The scores for each sewer length, derived from the 'likelihood' and 'consequence' models, are then multiplied together to form an individual sewer risk score.

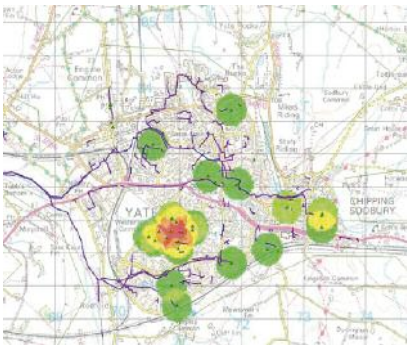


	Observed data from CCTV	Operational data from customer contacts	Historical asset failures	Engineering data based on pipe characteristics	Total weighting
Likelihood model weighting	0.55	0.15	0.25	0.05	1
	n/a	0.5	0.3	0.2	1

Above: **Fig 2 - Information used to build the likelihood model for each sewer length; Table 1 – Example of dynamic weightings to counteract missing data**
Below: **Fig 3 - Information used to build a consequence model for each sewer length**







Above left: **Fig 4 – operational hotspots**
Above middle: **Fig 5 – Asset failure hotspots**
Above right: **Fig 6 – Sewer risk scores illustrated geospatially**

Sewer lengths (each individually represented by a dot on the grid in the accompanying figure) towards the top right corner of the grid have a higher risk than those towards the bottom left corner. The sewer risk scores are then also portrayed geospatially to enable CCTV surveys to be targeted and grouped efficiently. Since Wessex Water has started using this risk-based targeted CCTV process, the company has seen the success rate (where success is deemed as finding structural problems that require rehabilitation) increase from 15% to around 50% (figure 6).

Summary

Establishing a better understanding of the rate of deterioration of long-life assets such as sewers has only been possible on the back of a long-term commitment towards data gathering over an extensive time period using a consistent survey format.

Sewer risk scoring, using a dynamic weighted approach to counter incomplete datasets, identifies sewers that are high 'risk' rather than just high 'consequence'. This leads to a better targeted CCTV programme enabling a more optimised rehabilitation programme. T&T

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13-17 SEPTEMBER
9th International Symposium on Rock Fragmentation by Blasting, Granada, Spain
Organised by the Universidad Politécnica de Madrid, this conference will cover all aspects of the blasting process. An accompanying exhibition will also be present. Contact: Scientific Coordination, Prof José Sanchidrián: Tel: +34 913367060; web: http://www.fragblast.org

29 SEPTEMBER
Tunnels and Tunnelling Conference 2009, London, UK
T&TI with the British Tunnelling Society present a one day conference packed with cutting edge site reports and technical content. Speakers include Martin Herrenknecht, Barcelona Metro Line 9, and a special presentation by key members of the Crossrail team that will include a Project Update, TBM requirements, Settlement and Monitoring Strategy, and the establishment of the Crossrail Academy. More TBA soon. Contact: Natasha Denney: tel: +44 (0) 208 269 7833; email: ndenney@progressivemediagroup.com

07-09 OCTOBER
58th Geomechanics Colloquy 2009 Salzburg, Austria
The popular annual event will be held in the Salzburg Congress Centre with session topics including Projects in Austria, Grouting in Rock, Deep Tunnels, and Reuse of tunnel excavated material. Contact: OeGG: email: salzburg@oegg.at: Web: http://www.oegg.at/events/geomechanics-colloquy

28-30 OCTOBER
China's 4th International Symposium on Tunnelling, Shanghai, China
Organized by :China Civil Engineering society; Shanghai Society of Civil Engineering; Shanghai Tunnel Engineering Co., Ltd. Contact: Mr Lou Ruyue; Tel: 86-021-54640607; email forum@tunnelling.cn; Fax: 86-021-54641018; web : http://english.stec.net/

NOVEMBER 2009
Hong Kong Tunnelling Conference 2009, Hong Kong
With more than 10 major infrastructure projects currently at the design and planning stage for the region, the Institute of Materials Minerals and Mining is organising this conference. Date and speakers TBA. A call for abstracts will be issued soon. Contact: Email: secretary@iom3.org.hk

4-5 NOVEMBER 2009
Nordic Symposium of Rock Grouting - Geotechnical Seminar - Rock Mechanics/Engineerin Seminar, Helsinki, Finland
Sponsored by ITA-AITES. Underground Space Seminar contact: Bjarne Liljestrand; tel: +358 400 362850; email; bjarne.liljestrand@sroy.fi. Rock Mechanics/Engineering Seminar contact: Erik Johansson; tel: +385 50 5112162; email: erik.johansson@sroy.fi. Nordic Symposium of Rock Grouting contact: Ursula Sievänen; email: ursula.sievanen@sroy.fi

18-19 NOVEMBER
12th International Conference of ACUUS, Shenzhen City, China
'Using the Undergound of Cities: for Harmonious and Sustainable Uran Environment' is the theme of this conference. Contact: Dr Guo Dongjun, Ms. Peng Xiaoli, Ms. Sun Xiaoyuan, Dept of Civil Engineering, Nanjing Engineering Institute. Fax: +86 25 84272793; email: ACUUS2009@163.com; web: www.mwwting163.com/kehu/auc/index.html

26-27 NOVEMBER
Austrian Southern Railway Link Conference 2009 Leoben, Austria
This event focusses on Austria's Southern Railway Link, specifically, the design and construction of the 32.8km long Koralm Tunnel and the 27km long Semmering Base Tunnel along the route. November 27 involves a site trip to the currently under construction Koralm Tunnel Lot KAT 1. Contact: Marion Kainrath: email: technologieakademie@unileoben.ac.at: Web: http://technologieakademie.unileoben.ac.at

01-03 DECEMBER
STUVA TAGUNG'09 Hamburg, Germany
Every two years the STUVA conference takes place with various topics from the fields of underground construction. The conferences draws some 1,500 tunnelling experts from more than 30 different countries. An exhibition accompanies the event. Contact: STUVA: email: info@stuva.de web: http://www.stuva.de/

27-29 DECEMBER
13th International Conference on Structural & Geotechnical Engineering 2009, Cairo, Egypt
This two day event will cover all aspects in the field of structural and geotechnical engineering, organised by the conference secretariat, Ain Shams University Faculty of Engineering, Structural Engineering Department. Contact: Prof. Dr Eman Soliman; tel: +2 02 26839318; email: Info@ICSGE2009.com; web: www.ICSGE2009.com

BRITISH TUNNELLING SOCIETY

17 SEPT: **Seismic Response of Tunnel Linings**
Segmental lining radial and circumferential joint behaviour during seismic activity and mitigating designs are discussed by Gary Kramer, Hatch Mott MacDonald. 6pm start at the ICE

15 OCT: **Channel Tunnel Repairs**
Following the fire in September 2008 in the Channel Tunnel, all aspects of the swift repair works will be discussed by Christian Maquaire of Eurotunnel. 6pm start at the ICE

17-19 MARCH 2010
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 Institute 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
Not long after the 2010 Winter Olympics, the International Tunnelling Association (ITA) visits the spectacular city of Vancouver, British Columbia, for its yearly conference and exhibition. The usual combination of working groups, open sessions and technical talks will all be included. Contact: web: http://www.wtc2010.org

8-10 JUNE
InterTunnel 2010 Turin, Italy
Tunnelling exhibition aimed specifically at clients, contractors and consultants involved in the construction of and equipping and operation of tunnels. Contact: Mack Brooks Exhibitions; web: http://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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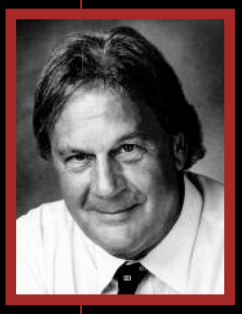

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