INTERNATIONAL EDITION
March 2016

Tunnels AND TUNNELLING

TYROL TEST

Lessons from the Kargi HEPP are to be put to the test on the GKI project

Shafts

Settlement mitigation

Screwbolts

EASY COME EASY GO

RELIEF WAS probably the general reaction when Seattle Tunnel Partners had been given permission to resume tunnelling by the Washington State Department of Transport (see news, page 10).

After years of delays to the project, and then a brief setback to do with a sinkhole and a tipped barge, the project will, hopefully, begin make progress.

In an interview this issue (see feature, page 20), Bob Ibell of London Bridge Associates talks about the ups and downs; the difficulties of being a contractor, difficulties that led to a previous employer of his abandoning tunnelling altogether for over a decade.

And while Seattle Tunnel Partners might hope things are looking up, for another contractor on the far side of the world things are looking far from positive.

IRB Infrastructure Developers has had the USD 1.5bn Zoji La Pass Tunnel contract stripped from it amid accusations of political corruption during the bidding process.

According to Reuters the company's stock value fell four per cent when the news was announced, before recovering shortly after by one per cent. The Zoji La Pass project reportedly accounted for three fifths of IRB Infrastructure Developers' order book.

The news that India's Transport Minister Nitin Gadkari cancelled the contract is a particularly painful setback, as it comes just after such a positive move for infrastructure spending in the country. In the latest budget announcement shortly before Tunnels and Tunnelling went to press, the country announced an infrastructure investment spending spree, notably including an impressive 22.5 per cent annual increase on road and rail spending, bringing the total to USD 33bn. Gadkari is seen as a standard bearer for infrastructure investment in India.

IRB Infrastructure Developers won the contract in January as the sole bidder, but the Indian Roads Ministry is quoted by Reuters as saying that the tender period had been extended several times. IRB Infrastructure Developer's managing director, Virendra Mhaiskar was also quoted by the news agency as saying the company had no idea why the deal had been scrapped.

The project is supposed to open up an all-weather route to Jammu & Kashmir with a 14.08km-long tunnel. The project has in the past enjoyed a lot of prominent political support. In one instance, People's Democratic Party (PDP) president Mehbooba Mufti spoke in favour of fast-tracking the tunnel project back in April 2012, saying that the tunnel would "unshackle the district of Kargil from physical and economic constraints."

She added that political apathy has held back the region, which she identified as having great potential.

While not as high profile internationally as the problems on the Alaskan Way Viaduct Replacement Project have become, sympathies surely go out to another contractor – and particularly in this case its workforce – struggling in the face of a sudden and enormous change in fortunes

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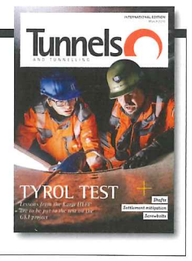
What do you think? Send your views to the editor and join the debate

Alex Conacher
Editor

Cover

The cover image shows work ongoing at the GKI hydropower project in Tyrol State, western Austria



Next issue

In the next issue of Tunnels and Tunnelling, we have a potlight on the Australian tunnelling market, as well as project reports from North America, South America, Asia and the Middle East. We also take a special look at the Grosvenor Mine Expansion in Australia.

This month...

20 YEARS AGO

Ground freezing is being used in a salt dome in Louisiana, USA to stabilise the ground while millions of barrels of oil stored there by the government are retrieved. The extensive Morton Salt Company's mine workings, over 220m deep, were used to store 75M barrels of crude. But a seepage of groundwater has disolved the surrounding salt, causing a sinkhole 10m in diameter at the surface where the soil cover over the salt dome is 60m thick. The sinkhole has been progressively backfilled and an injection of saturated salt brine has minimised further subsidence.
Tunnels and Tunnelling, March 1996, p.9

30 YEARS AGO

Markham will manufacture Robbins full face TBMs at its factory in Chesterfield, UK and in certain selected overseas territories. This announcement comes only six months after Markham decided that due to continuing poor demand, and the current climate of high risk, fierce competition and low returns, it was to withdraw from the civil tunnelling machine design and supply market. It would however continue to supply equipment to the UK National Coal Board, a traditional customer, and would fulfill its agreement with Okumura of Japan for the supply of slurry shields. Markhams withdrawal has left Britain with no designer or manufacturer of full face hard rock TBMs. With the Channel Tunnel about to begin, it leaves Britain in an embarrassing situation.
Tunnels and Tunnelling, March 1986, p.9

Above: The TEP II project in Mexico is featured on page 26

Key people in this issue

ANDREW SMITH
A longstanding member of the Tunnels and Tunnelling International Editorial Advisory Board, Andrew graduated from Leeds University with a degree in Civil Engineering and is a Chartered Civil Engineer. He has worked for over 50 years in the UK Tunnelling Industry on a wide variety of schemes in the employment of Kinnear Moodie, Streeters of Godalming, Costain and Joseph Gallagher where he currently employed as a Consultant. In this issue he shares his experience with design and construction considerations for caissons and shafts. Read his article on page 39.

BOB IBELL
Bob is a former British Tunnelling Society chairman and current chairman of London Bridge Associates (LBA). The article on page 20 gives some highlights from a long and successful career, covering his time employed at Taylor Woodrow, as well as the founding of LBA with colleagues from Taylor Woodrow's tunnelling then-abandoned tunnelling business unit. Bob also has a word of advice for young engineers starting out in tunnelling, and gives his thoughts on what has changed in his time in the industry, and in some cases what the industry has lost.

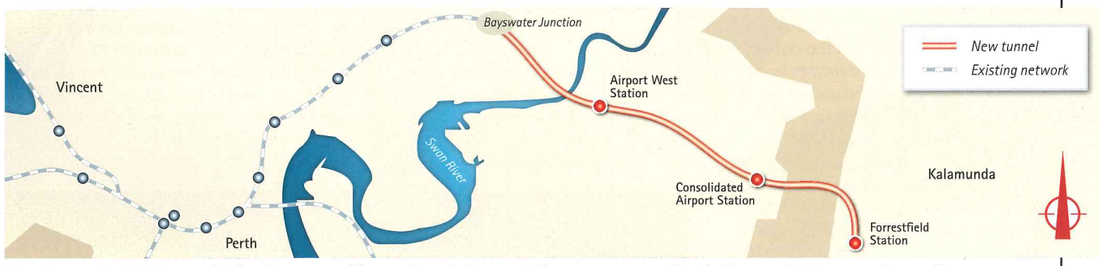
FORRESTFIELD-AIRPORT LINK PREFERRED BIDDER ANNOUNCED

AUSTRALIA — Perth's major new rail project has revealed its preferred joint venture. The Salini Impregilo - NRW JV is tipped to fulfill the main design and construct contract for the USD 1.43bn Forrestfield-Airport Link. The other shortlisted groups were a JV of ACCIONA Infrastructure, BAM International and Ferrovial Agroman; and a JV of John Holland and Leighton Contractors.

It brings to an end the 15-week period of evaluating proposals from the three shortlisted groups. The proposals were judged on a combination of their price and plans for design and construction, as well as innovation, stakeholder engagement and delivery management plans.

The Public Transport Authority will now enter into negotiations with Salini Impregilo - NRW to finalise the contract by May after which more information about the project will be made publicly available. Construction will start later this year and the first trains are expected to run on the line in 2020.

"We envisage the contractor will mobilise on site in the coming months," Dean Nalder, Minister for Transport for Western Australia said. "This is an incredibly exciting time for a project that will change the way the people of Perth, and in particular Perth's eastern foothills, travel to our city. Planning for this transformational project is well advanced."



The Forrestfield-Airport Link alignment. The project brings public transport to Perth Airport in Western Australia

Cowi North America formed

NORTH AMERICA — Buckland & Taylor, Jenny Engineering Corporation and Cowi Marine North America have joined to form Cowi North America.

"Our decision to merge and rebrand at this time was deliberate," said Cowi North America president and CEO Steven Hunt. "We see strong growth in the demand for our specialist services combined with our clients looking for new ways to deliver their projects.

"Our clients entrust us to combine our very specialised engineering expertise with project leadership to handle ever larger and more complex projects for them. We see this as an optimal time to combine our North American specialist businesses and lever the global scale of Cowi in the bridge, tunnel and marine market."

Steven Hunt will remain president and CEO of Cowi North America. The company announced that new appointments for the tunnel business were expected shortly

6 Alpha launches EOD division

GREAT BRITAIN — A dedicated 'Explosive Ordnance Disposal' (EOD) division has been launched by 6 Alpha Associates, a risk consultancy with expertise in the assessment and management of unexploded ordnance (UXO). The company said it had noticed increasing demand from UK construction companies for a strategic approach to managing UXO. The industry has, according to 6 Alpha, faced an escalating UXO risk in recent years.

A spokesman added: "This risk is not only posed by the sizeable legacy of unexploded ordnance left behind following two World Wars, as well as years of munitions dumping and extensive military training but also the fact that legal duties in general and those associated with safety in particular, have become much more demanding.

"Whilst 6 Alpha has assisted the construction industry to mitigate this risk over the past decade, principally through the provision of consultancy, the business has now taken the decision to invest in the specialist survey equipment required in order to deliver explosive ordnance risk management services on-site too."

Grace names senior vice president

USA — W. R. Grace & Co. announced Thomas Blaser has been named senior vice president, finance, and is expected to be elected senior vice president and chief financial officer effective immediately following the filing in late February of the company's Annual Report on Form 10-K. At that time, Hudson La Force is expected to resign as chief financial officer. La Force was named president and chief operating officer on 4 February.

Grace chairman and chief executive officer Fred Festa added: "Tom is a proven leader with strong specialty chemical industry experience with global companies.

Festa continued: "He will be a great addition to our leadership team as we grow our business, maintain our ROIC discipline, and increase productivity through manufacturing excellence."


A pile of old unexploded ordnance recovered from northern France

MTA APPROVES FINAL MAJOR CONTRACT FOR EAST SIDE ACCESS MANHATTAN CAVERNS

USA — The Metropolitan Transportation Authority (MTA) Board approved the final major contract for the East Side Access project, which will build and finish four platforms and eight tracks for the new Long Island Rail Road (LIRR) terminal some 100ft (30.5m) below Grand Central Terminal, it announced on January 27.

The Manhattan contract will transform two 1,143ft (348m)-long caverns carved out of solid rock into a terminal station, with more than 12 miles of track work from Queens to Manhattan, including eight tracks and four platforms in the station; elevators, escalators and staircases to carry customers to and from the underground station; and all architectural finishes through the caverns.

"With the award of these contracts, the eventual completion of East Side Access is starting to come into view," said Michael Horodniceanu, President of MTA Capital Construction, which is building the project. "This is the next chapter in the long history of Grand Central Terminal and the growth and development of New York City."

The MTA selected the Tutor Perini Corporation for the three-and-a-half-year caverns project at a contract value of USD 663M. During the year-long procurement process, 34 firms requested the RFP documents and seven submitted separate technical and cost proposals. The selection committee unanimously selected low cost proposer Tutor Perini from among three firms that submitted best and final offers.

The contract to make upgrades to railroad infrastructure in Sunnyside, Queens, was also awarded to Tutor Perini Corp., in December, and is valued at up to USD 79M.

The upgrades will enable LIRR trains to access Grand Central Terminal.

The work the contractors will perform in Sunnyside includes excavation and construction of an approach structure that will allow the LIRR's existing tracks to connect to one of the four rail tunnels that have been built below Sunnyside Yard. This will complete the physical connection that will run from the tunnels under Grand Central all the way to daylight in Sunnyside, Queens. Approaches to the other tunnels will be built separately through other contracts.

Workers will also replace of one of the five bridges that carry tracks over 48th Street. Additional work that will be performed under this contract includes switch installation; retaining wall construction; installation of electrical utilities; demolition of an electrical substation; and installation of overhead wire support structures.

The contract is structured to take 19 months and is valued at USD 53.3M. If the MTA deems that the work is going well, the contract allows the authority to exercise options valued at approximately USD 26.5M that would expand the scope of work to be undertaken and extend the duration of the contract to a total of 30 months. Construction activities for this contract are planned to be underway in late February.

The East Side Access project will increase the LIRR's capacity into Manhattan, and dramatically shorten travel time for Long Island and eastern Queens commuters travelling to the east side of Manhattan. East Side Access is scheduled to be completed in December 2022.

Early cavern work on MTA's East Side Access project This photo shows work on going in October 2013. *PHOTO: METROPOLITAN TRANSPORTATION AUTHORITY / PATRICK CASHIN*

Atlas Copco adds staff in rental division

USA — Atlas Copco announced on February 26 its Rental Division appointed four managers to lead its growing rental market. Steve Nelson serves the national rental aftermarket as a business development manager, Norbert Matthews works as an area sales manager for the Midwest, Charlie Clarkson serves the Northwest as the area sales manager and Ronald Repasz is the area sales manager for the Southwest.

"We're committed to building strong business relationships with our customers. Part of that is building a team that continues providing industry-leading assistance by offering the best equipment, parts, service and aftermarket support," said Matt Cadnum, Atlas Copco rental channel vice president of sales.

Together, the four new managers have more than 40 years of industry experience.

Metro names Crenshaw/LAX TBM

USA — The Los Angeles County Metropolitan Transportation Authority (Metro) held a TBM lowering ceremony on February 1 for the Crenshaw/LAX Line.

The TBM, a 6.5m-diameter Herrenknecht machine, named for Harriet Tubman, will be used to excavate twin 1.6km tunnels at the northern end of the new rail line.

Metro says the TBM will be lowered by segments and assembled underground in the next few weeks. Boring is expected to last approximately 13 months.

The 8.5-mile Crenshaw/LAX Line is a USD 2.058bn light rail line that will run between the Green Line and the Expo Line. It will have eight new stations to serve the Crenshaw, Inglewood and LAX communities. The project is being built by Walsh-Shea Corridor Constructors, comprised of Walsh, Shea, HNTB, Comstock and Arup. It is expected to open in 2019.

Bay Tunnel wins award

USA — The Bay Tunnel project has been named the 2015 American Society of Civil Engineers (ASCE) Region 9 Outstanding Water Project. The 8km-long, 4.6m id tunnel was brought into service in October 2014, well ahead of an original 2015 schedule.

The project, designed by Jacobs Engineering and constructed by a joint venture of Michels, Jay Dee and Coluccio, was also under budget at USD 288M. It was expected to come in at USD 313M.

The tunnel component is the first bore ever made underneath the Bay – the old pipes sit on the bed – and so the geology was a relative unknown.

Test drill probes indicated mostly clay but with embedded sand lenses up to 0.6m thick and there was an outcrop of the San Francisco complex, harder ground running for some (250m)

A Hitachi Zosen EPBM was chosen for the bore, and was designed primarily for soft ground but was fitted with shell bits for harder rock. Shell bits are rippers, but with a concave shape like a seashell. The contractor said the machine performed well and project manager Ed Whitman said it was one of the best machines he had ever worked on. Pressures of up to 3.2 bar was encountered.

A spokesman for McMillen Jacobs Associates added, "The presence of environmentally sensitive habitats on the Bay margins precluded using cut-and-cover pipelines, which resulted in the need for an 8km-long tunnel with only launching and receiving shafts and no intermediate construction shafts."

DLZ adds four new hires

USA — DLZ announced February 29 four additions to the firm's Michigan division. Ricardo Jackson joins the Detroit office as a business development coordinator and Robert Jordan, AIA (project manager), Robert Welch (construction department manager) and Kyle Slavik (structural engineer) all join the Lansing office.

Jackson has more than 10 years of experience in business development and was responsible for nearly USD 8M in sales over two years as a business development manager at a former organisation. He brings a wealth of experience in all aspects of business development strategy and has developed comprehensive programs for broadening the customer base and establishing critical industry partnerships. As a business development manager for a small engineering firm in Michigan, Jackson developed and implemented national growth strategies that tripled gross contract receipts from USD 2M to USD 6M.

Jordan's 20 years of experience includes a variety of project types and sizes including renovations and new construction projects for industrial clients, federal, state, and local government agencies. He is a Licensed Architect in Michigan, Ohio, Pennsylvania, Texas, Missouri, Florida, New York, and Illinois and is NCARB Certified. He offers a practical and proactive approach to problem solving and project coordination, bringing a wealth of knowledge to DLZ's architectural practice. He will focus on DLZ's services in Southeast Michigan.

As a former Michigan Department of Transportation (MDOT) employee, Welch has more than 11 years of experience in the construction engineering industry, where he successfully led more than USD 150M of construction contracts. Welch will manage DLZ's Construction Department where he will serve as the project manager on infrastructure projects, provide construction administration/ management services and oversee inspection and testing staff. Slavik is an engineer in training and holds a Master of Science in Structural Engineering from Michigan Technological University. He has civil engineering experience in concrete footing design, bridge and site inspections, structural analysis and field testing and sampling for soil, concrete, and asphalt.

SEATTLE TBM BEGINS MINING ONCE AGAIN

USA — Washington State issued conditional permission to resume tunnelling operations to Seattle Tunnel Partners (STP), which resumed mining on 23 February. WSDOT said it conditionally lifted the "suspension for cause" that halted mining and barging-related activities last month following two safety incidents. "As part of the conditions for lifting the suspension for cause, STP will be permitted to tunnel forward and install around 25 rings. During this time, they must demonstrate that they have implemented a number of changes to ensure they can safely continue mining."

These changes include: Updated tunnel work and quality plans, including calculations of the amount of soil removed during excavation of each tunnel ring; realignment of key personnel within their quality assurance program; new quality assurance protocols; new personnel at key positions within the tunnelling operation; restructured daily tunnelling meetings that include additional participants and protocols.

WSDOT said it made the decision to conditionally lift the suspension for cause after its team of tunnelling experts evaluated documentation submitted by STP over the past several weeks. While mining can resume, barging activities are still restricted pending submittal of additional documentation. STP will remove excavated soil by truck as they continue addressing the barging issue. Repairs to the pier that was damaged during the January 12 barging incident were completed earlier this month.

Work was suspended for cause on January 14 per section 14.2 of the contract, which says the state can suspend work without liability to WSDOT under a number of conditions, including the contractor's failure to "correct conditions unsafe for the project personnel or general public."

The suspension for cause only addressed tunnelling operations involving the TBM and the loading of barges at the site. It did not apply to the other ongoing work under the design-build contract with STP or any other contracts being managed by the viaduct program. The conditional lift will remain in place for approximately 160ft (49m) of tunnelling. During this period – which is considered part of STP's initial testing phase – STP will be operating with additional communication with WSDOT and its tunnelling experts. If STP demonstrates that their revised mining procedures are effective, crews will continue mining an additional 100ft (30.5m).

"STP has addressed the issues that led to the suspension for cause. This conditional lift of the suspension for cause will give STP an opportunity to demonstrate the effectiveness of their updated mining procedures," said acting transportation secretary Roger Millar. "[This] project has always been about safety. We must continue our work to replace the viaduct, but we have an obligation to ensure that work proceeds safely. We will continue to work with STP while taking whatever steps are necessary to protect the interests of the public moving forward.".

As of early March the TBM has bored approximately 33.5m since STP resumed mining. The machine has tunnelled a total of 424m. WSDOT said, "STP is now 17 concrete rings into the 25-ring demonstration period that was put in place when WSDOT conditionally lifted the January 14 suspension for cause. Crews are mining north to a planned maintenance stop just south of Yesler Way. Once there, they could spend several weeks performing maintenance before the machine tunnels beneath the Viaduct."

LTA ISSUES CROSS ISLAND LINE EIA RESULTS

SINGAPORE — The Environmental Impact Assessment for the stretch of Cross Island Line around the Central Catchment Nature Reserve has been issued. It concluded that the proposed site investigation works would cause 'moderate impact' on the few parts of the reserve where works are to take place.

LTA stated that it was studying two alignment options in the vicinity of the reserve, requiring an EIA, site investigation works and a feasibility study. The results of these will be considered along with other factors such as transport connectivity, travel times, costs, and impact on home owners and other land owners and users when deciding the eventual alignment.

The line was announced in 2013 and will double the length of the rail network in Singapore by 2030. Running for approximately 50km, it will be the eighth such line in Singapore.

LTA Chief Executive, Chew Men Leong said, "Since the announcement of CRL in January 2013, we have worked closely with nature groups, the National Parks Board, and engineering experts to study the best way to conduct site investigation works in the vicinity of Central Catchment Nature Reserve. We have incorporated the valuable views and suggestions of the nature groups in the report. The findings from the engineering feasibility study and the site investigation will provide critical information to help the Government make a considered decision on the CRL alignment that best serves the public interest."

Ottawa taking abstract submissions

CANADA — The TAC 2016 Ottawa website is live and ready to accept abstract submissions. The event is planned for October 16–18 at the Shaw Centre in Ottawa, Ontario.

TAC is accepting abstracts for the conference. Submissions of up to 300 words are due by March 25, 2016 and must be submitted electronically.

"Capitalising on Underground Infrastructure," the 2016 TAC conference will include plenary presentations, technical sessions, and a trade exhibition all designed to highlight advancements in tunnelling design, construction and delivery – in Canada and around the world. Visit www.tac2016.ca for more information.

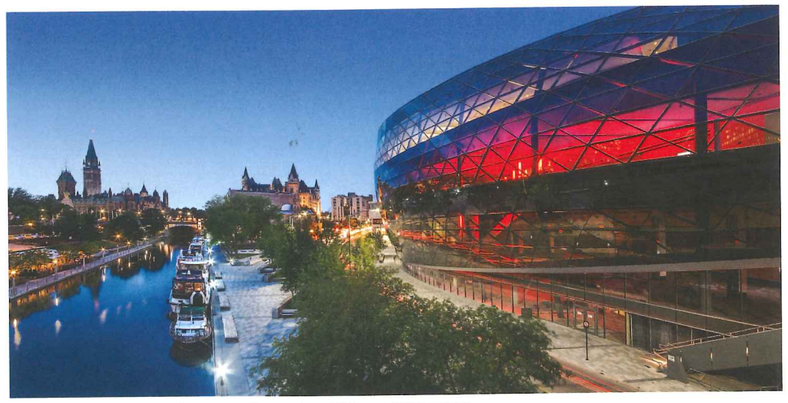
Counters Creek sewer consultation

GREAT BRITAIN — Second phase public consultation sessions for the Counters Creek storm water relief sewer have begun. The project, to be constructed in west London, involves construction of a 5km-long 4m-diameter sewer tunnel connecting to existing infrastructure and leading to the Thames.

The tunnel is around 40m deep and will be entirely in London Clay. It was originally intended to be deeper, but changes to Crossrail 2 plans allowed this to be revised following the first consultation phase. The tunnel will be constructed by TBM.

The project is a response to the flooding of basement apartments in the area around 10 years ago. According to a Thames Water employee, basements were turned into houses following construction of the Thames Barrier, which reduced flooding. However an extreme rainfall event overwhelmed existing sewers and submerged properties.

Most of the current objections focus on the five shaft locations.



The Shaw Centre in Ottawa, Ontario will host TAC 2016

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

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Letter

Dear Sir,

Regarding the Farnworth Tunnel article (Tunnels and Tunnelling International, February 2016, p.32), since when did an open shield with digger arms become a "TBM"? Maybe the "Japanese-English" term of "shield-machine" would have worked?

There used to be an ITA Working Group (WG) defining terminology in a publication, though I am not sure there is a current version. Perhaps someone from that WG could update us? Regardless of that, I am sure most tunnellers use the term "TBM" to mean a shield with an inbuilt rotating cutter-head. Maybe others would say that definition is now outgrown but a digger-shield (which is what we often called equipment like that used at Farnworth) clearly does not "bore".

There is an odd conflict here though in that in traditional British tunnelling terms "bored tunnel" does not mean a tunnel bored by a TBM, it simply means a mined tunnel in the sense that it is "not cut-and-cover". However, that tunnel engineers' meaning seems to have been dropped by overseas folk when using English to talk about their tunnels and international (non-technical) English has taken over such that people do use "bored tunnel" to mean "TBM bored tunnel".

Regards,

David Caiden
Director, Arup

Left: Sandvik DT1131-SC jumbo in operation at the Cumbres de Llano Largo Mountain tunnel in Mexico. The 3.2km-long drive should be finished in July for a cost of USD 213M. It will be the longest road tunnel in the country. The maximum excavation area achievable by the equipment is 18m across by 11m high

IT'S WARMER DOWN BELOW

Paul Perry reviews Sir Harold Harding's autobiography: *'It's warmer down below'*, edited by Amanda Davey

Paul Perry
Paul is an associate director within the CH2M Tunnelling Group, and a BTS Member

SIR HAROLD HARDING is not only well known in the tunnelling industry, but was also a founding member of the British Tunnelling Society. This biography includes additional chapters by his granddaughter, Amanda Davey and describes his work, including that with both Mowlem and Soil Mechanics, and is set around some of the major construction and tunnelling projects of the time, including the Channel Tunnel. Written in various sections through his career, by date, by event and by project, it is a pleasurable and fascinating read that will keep the reader enthralled throughout. Indeed, in his forward, Douglas Parkes includes a quote "send him to me and I will put him down a hole" as a typical Hardingism. This resonated with me, for as a young graduate engineer at Grain Power Station I too had to look "down a hole" on the instruction of the very experienced and thoroughly in charge Senior Resident Engineer before getting my wings. Perhaps they were made from the same mould.

The biography is exhaustive in detail and extensive in wisdom. The people Harding engages with equate to the telephone directory of the great and good of the industry at the time and this may prove of interest to today's graduate and technician, as the names of some of the companies quoted in this book have disappeared, such as Kinnear Moodie, John Mowlem and Company, Sir Alexander Gibb and Partners, Sir William Halcrow and Partners to name but a few.

In the first chapter, Harding describes how not even lectures in Structures from Sir Ralph Freeman and Oscar Faber, could not allow him to detect a spark of structural genius in him. However Harding advises that as his life developed, "it was seldom called into use and gradually eroded away from lack of exercise".

Next is a section of Harding's recollections at the start of his career relating to the London Underground tunnels in the 1920s, including a passage on the phenomenon of the "greasy backs" which were encountered in the London Clay and seen to be a threat to the tunnelling at Mornington Crescent.

The book covers Harding's work at John Mowlem and Company describing the inner workings of a contractor as having "a chief engineer to be the equivalent of an Admiral and each separate contract would be a ship individually captained by a man known as the agent". This naval analogy is an interesting approach to organisation and management. Harding's own views on the industry, and his comment on modern large firms, the plethora of staff and the smoke screen of control, become evident.

There are numerous entertaining anecdotes within the text, including that of the infamous "Bumper" Harris. Harding worked on Mornington Crescent Station where the junction chambers were supervised by "Bumper" Harris who had lost a leg at Waterloo Station while building the Bakerloo Line. In 1977 a question in a BBC Mastermind programme produced the answer that "Bumper" Harris was the man with a wooden leg who kept traversing the first-ever escalator at Earls Court, to encourage the nervous.

Another anecdote relates to Harding's work as a Company Director and the need to intervene for the betterment of a project, such as in Oban, where Harding's telephone call is put through to the Senior Partner of Halcrow in order to insist on the introduction of steel arch ribs to support the tunnel to advance the works. This suggestion is described as being met with reasoned acceptance, although one wonders if the "by-passed Resident Engineer" might have seen it all a little differently. By now a military analogy has been introduced to replace the previous naval approach. With the "troops" moving from job to job, directors become generals and the engineers are the officers ably assisted by foremen and gangers as NCO's.

Harding's overseas trips are just as enlightening, a memorable one being with the Resident Engineer from Sir Alexander Gibb and Partners at Owen Falls Dam to deal with materials shortages in Uganda at the time. This was written up in the proceedings of the ICE. I was once shown a reinforcement detail of the headhouse where rails (for the rail track) had been used in a column in lieu of reinforcement.

Even when Harding leaves Mowlem, the work continued to follow him and previous contacts provided gainful employment. One such example is when Vernon Robertson, a partner at Halcrow asks "can you possibly visit Bombay on our behalf in October, as we are very stretched?"

The later chapters describe Harding's work in various arbitration cases and the Aberfan tribunal, with the book concluding with Harding's involvement in the setting up of the BTS. In conclusion, this is very worthwhile read and whether you are a tunnel, a civil or structural engineer, there is something for all in this impressive history of one of the industry greats

Get the book

The full publication *'It's warmer down below'* is available for GBP 19.95 (USD 28.14) from Tilia Publishing.
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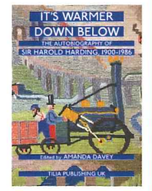
www.tiliapublishinguk.co.uk



LONDON'S WTC BID

Two icons of London: the Houses of Parliament Clock Tower and the Underground
PHOTO: PROCHASSON FREDERIC / SHUTTERSTOCK.COM

GREAT BRITAIN — The British Tunnelling Society has formally announced its candidacy to host the World Tunnel Congress and ITA General Assembly in 2019. The capital London is the city put forward by the BTS steering committee for the bid in January 2016. The vote will take place at WTC 2016 in San Francisco this April.

As well as the city's world class facilities and abundant tourist attractions, the 100-page bid looks at the impressive investment in underground infrastructure recently enjoyed by the capital, as well as the upcoming pipeline of works. By 2019 the UK will be celebrating the completion of Crossrail, the largest current infrastructure project in Europe. Crossrail will actually be in service by this point, propelling international visitors through the capital from Heathrow Airport directly to the planned WTC 2019 venue: the ExCel Exhibition Centre.

At the same time, major tunnelling investment for the Thames Tideway CSO project in London will be underway and substantial works of the second high-speed rail link in the UK, from London to Birmingham, will be progressing.

Additionally, the UK will be celebrating the 25th anniversary of the iconic Channel Tunnel subsea rail link to the continent, the Institution of Civil Engineers will be celebrating its 200th anniversary, and the Brunel Tunnel under the Thames River will have provided more than 175 years of continuous service.

A spokesman for the BTS said: "The UK is recognised as a spiritual home of modern era underground and tunnel engineering, with the Brunel Tunnel being the first subaqueous tunnel through soft ground and using a mechanical shield. From there, British engineers have continued the process of development and innovation, culminating today in the application of state-of-the-art techniques and the introduction of new systems in the fields of robotics, electronics and installations for long-term monitoring of underground structures through their design-life. This historic and current connection to the tunnelling industry in the UK inspired selection by the BTS of the conference theme 'From Pioneering to Modern Possibilities.'"

The spokesman added: "The UK and the BTS has a long connection with the ITA-AITES. It is one of the original founding nations of the Association and Sir Alan Muir Wood, as its first President (1974 - 1977), became its Life-Time Honorary President. The annual Muir Wood Memorial Lecture in the opening session of every WTC is a legacy to Sir Alan's commitment to the worldwide tunnelling industry.

"The BTS then nominated and supported two further UK Presidents of the ITA in Colin Kirkland (1989 - 1992) and Martin Knights (2007 - 2010). In addition, BTS members are heavily involved in the ITA Working Groups and the ITA Young Members forum. The society remains a champion of the workings of the Association and its future expansion. BTS last hosted the WTC in 1991 and would relish the opportunity to host the international delegation in 2019."

READ, LEARN, THINK

After several requests from British engineers, *Tunnels and Tunnelling* speaks with **Bob Ibell**, chairman of *London Bridge Associates* about his career and the unusual set up of his current company, which was formed to escape the whims of corporate decision-makers, and secure work across the project life cycle

THE SCOTTISH university system afforded a "narrow escape from quantity surveying" for the young Bob Ibell, who confesses to making a mess of his A Levels. Higher education in the northernmost part of the UK runs a year behind the rest of the country, and a foundation year gave him the opportunity to catch up with his peers at Aberdeen University and qualify with a BSc in Civil Engineering.

"I wanted a fair degree of outdoor life," says Ibell "and I took some advice from my father, who was a teacher not an engineer, and we settled on engineering as the path for me."

After university, during the late 1960s, the major work in the UK was in nuclear power. Taylor Woodrow appeared the most attractive to Ibell, and he joined its construction division in 1967.

THE MOVE TO TUNNELLING

One of Ibell's early forays into underground construction was at Heathrow Central Station in west London. The station structure has an unusually thick (2m) roof slab, which was particularly unusual in those days, but was designed to support the weight of a yet-to-be-built hotel. Ibell was then dispatched to the northeast of England because a similar station box was required for the Tyne and Wear Metro. Work constituted 1.6km of largely roadheader-excavated twin tunnels in coal measures and was delivered by the 'Thyssen-Taywood JV'. It saw Ibell starting work in the Gateshead area in January 1976.

"At Gateshead I was number two to Dai Heycock. He, aided by Maurice Gooderham, BTS regulars, vowed to teach me about tunnelling. I'd almost got the tunnelling 'bug' by now, but I did try to break away a little later when everything was quiet."

On hiatus

Ibell left tunnelling briefly in 1982 in favour of the oil industry, at Taywood Santa Fe. It was a period of very little tunnelling work in the country. Civil engineering as a whole was fairly flat. No experience is bad experience, and this time in the wilderness gave him experience with database principles and knowledge of the Artemis software group.

"This all ended when the bottom dropped out of the oil price – does that sound familiar? The contract got shelved, but I was told: 'we have a job at Heathrow'. And so I was back, the same place. The place I had left to go to the Tyne and Wear Metro. But by this point of course the project was a lot further on."

CHANNEL TUNNEL

Ask many of the experienced tunnel engineers from the UK for a highlight in their career and there is one project that emerges in conversation again and again: the Channel Tunnel. Ibell thinks himself fortunate to have been able to see the whole scheme through.

"It all started in late 1984. It was just before Christmas and I was heading off for the holidays early when I got pulled back for a meeting.

"We were hoping to get the Channel Tunnel and so we sat down and went through the programme."

This was the programme that survived to the end of the project and was the benchmark for work throughout.

Shortly afterwards Ibell went to work for the Channel Tunnel Group; one of the groups that submitted the Channel Tunnel design and build proposal to the government. Ibell was responsible for preparing the tunnelling side of the submission. The submission was successful and he was faced with the decision to stay with the client or join the contractors. He decided to go to the contractors, and was responsible for an awful lot of the early work on the project. Getting the whole thing set up.

"One memory is very clear: sitting down with the French to agree the parameters of the scheme; making a few decisions such as what the service tunnel was going to look like. The only problem was that we were building a rail tunnel and they were building a road tunnel."

There was a lot of support for a road tunnel, especially from UK Prime Minister Margaret Thatcher, but even now a road tunnel under the English Channel is considered highly problematic technically. Largely due to ventilation concerns.

But despite the financial problems on the project, the technical achievement has left the UK and France with a modern Wonder of the World.

Career timeline

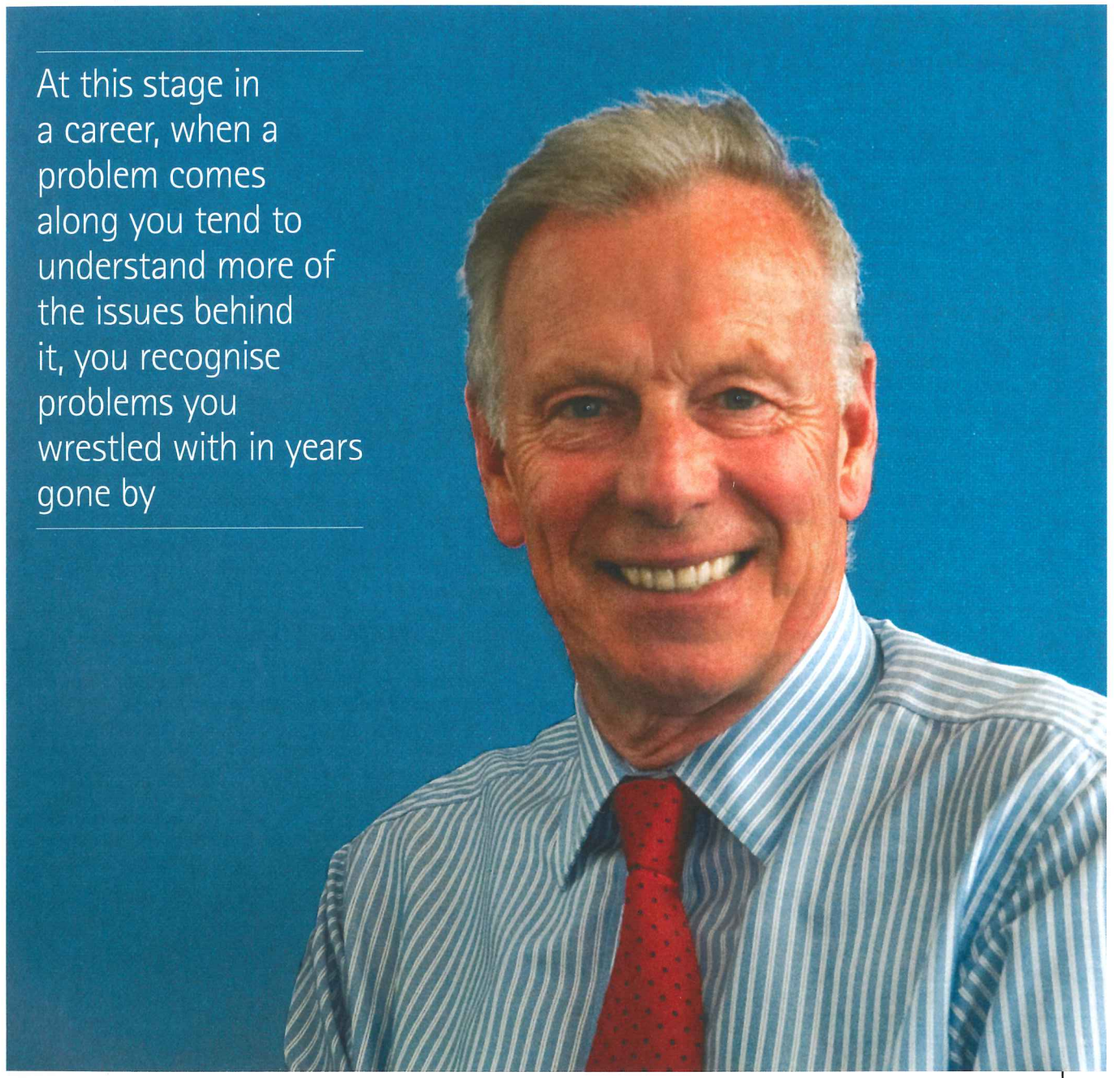
London Bridge Associates (2000-present)

- ***2013-present*** LU chairman of catastrophic risk working group
- ***2013-present*** KL Metro Extension
- ***2012-present*** HS2 Phase One with Mott MacDonald
- ***2008-2012*** LBA leader and BTS chairman
- ***2008-2008*** King's Cross Upgrade Project with Network Rail
- ***2006-2007*** Consultant for Swiss Re, Mott MacDonald, Gifford and BBM
- ***2005-2006*** M25 Holmesdale Tunnel Refurbishment with Costain
- ***2000-2005*** CTRL Contract 240 with Costain, Skanska, Bachy

Taylor Woodrow Construction (1967-2000)

- ***1998-2000*** Operations director for UK and Western Europe
- ***1996-1998*** Head office: director
- ***1993-1996*** Jubilee Line C104 and C103, resident contracts manager
- ***1990-1993*** Head office: contracts manager
- ***1987-1990*** Channel Tunnel deputy construction manager
- ***1985-1986*** Channel Tunnel Group tunnel manager
- ***1983-1984*** Piccadilly Line Extension, project manager for Thyssen Taywood
- ***1978-1983*** Marine Projects, agent
- ***1976-1978*** Tyne and Wear Metro, deputy agent for Thyssen Taywood
- ***1973-1976*** Heathrow Central Station, chief engineer for LU
- ***1972-1973*** Head office, design engineer for nuclear and viaduct projects
- ***1967-1972*** Nuclear Power Works, site engineer

At this stage in a career, when a problem comes along you tend to understand more of the issues behind it, you recognise problems you wrestled with in years gone by



*Above: **Bob Ibell has been with London Bridge Associates since its formation***

FINAL YEARS AT TAYLOR WOODROW

The 1990s saw Ibell working as a resident contracts manager on the Jubilee Line Extension project in London. Work covered the construction of London Bridge Station (for which his later company is named) and the running tunnels associated with Southwark Station. This work included machine-driven tunnels, sprayed concrete linings as well as permanent in-situ linings on tunnels up to 11m in diameter. Additionally expansion of an existing and construction of a new ticket hall called for possibly the largest excavations in London Clay at the time.

After this, he was made a director

at the company's head office and was responsible for tunnelling and foundation engineering. But before long a strategic decision was made by the company to move out of the tunnelling industry and into other lower risk areas of business. And it seemed a number of engineers who had "caught the bug" as Ibell puts it would be looking for new employers.

Appetite for tunnelling

The board of Taylor Woodrow did not have the appetite for the contracting game at that time, says Ibell, adding: "we all know contracting is not an easy game. And particularly major contracting where you're working with one-off clients, ones you don't have a relationship with. And when you are doing that, it is a risky business. You only have to look at the contractors in the UK market at the moment to see that it is attractive to diversify to take risk out. Taylor Woodrow had five major divisions, and each had their day. The trick is to keep moving.

"If you start talking about the overseas market, UK companies have lost a whole load of money. Boards in our country do not seem to have the appetite; they want a company that acts in a responsible manner. They are not prepared to get in to the ducking and diving that you need to do contracting all over the world.

"Foreign companies that have success abroad tend to need a solid home market, with a more or less guaranteed share of the work to take the risk abroad."

Above: ***The Hindhead Tunnel project***

Below: ***Bridge slide operation at White City in London***

Consultancies, Ibell points out, do not suffer from the risk quite so much as they sell their expertise rather than taking on a lot of risk.

LONDON BRIDGE ASSOCIATES

Following the Taylor Woodrow announcement, Ibell and his colleagues were sitting in an office above a tapas bar in Central London and conversation drifted from their futures to the problems of contracting in a boom-bust pipeline of work environment. The idea of banding together and selling their skills as a group emerged. They completed the extant Taylor Woodrow contracts, and Taylor Woodrow made no effort to block or hinder the gathering of the new group of engineers.

"We were setting out to sell our skills across the entire construction cycle of a project," says Ibell, "which is funny because as contractors we were always of the view that consultants never added value. So almost as a founding pledge we decided to only work where we could add value. And in fact we make a point of telling clients when we think there is nothing more we can add to a project."

The new company took a lot of convincing for some people, but the idea of not being at the whim of anyone, and not being at the whim of the industry cycle was appealing to the initial team of seven. All of which had been contractors for many years and knew the feast-famine cycle well.

Funding and initial setup

Rather than going to the bank and borrowing the necessary funding, the newly formed LBA all committed up to GBP 3,000 to cover initial expenses and then worked three months for free. At the end of this point they agreed on a couple of the group to become directors, someone became secretary, and an organisational structure was set up that could be taken forward.

"This was June 2000. We drafted employment letters to ourselves, issued share certificates and got the company away. We tried to make certain to never come to a point where we had arguments. We agreed the main purpose of the company was to provide work, rather than making lots of money for ourselves. We set the company up so that you cannot own shares unless you are actively working. As someone retires, they have to sell their shares."

Reflections on the industry

"There have been a few changes in my career:

- A major one is the growth of subcontracting. When I started out we employed our own labour. As a young engineer I had to actually understand the outputs; I had to set and propose bonus targets, I had to actually compile a bonus sheet and justify that at the end of the week as well as my normal setting out, quality control and planning work. You were really a 'Jack of All Trades' in those days. Today things are a lot more specialised in terms of what an engineer does. They will tend to have a narrower area of responsibility. Although there is a lot more form filling, be it computerised or paper. And of course, the engineer of today has a lot more safety responsibility.
- We are safer; there are fewer fatalities. There is a lot more detailed attention to health and safety, but it is interesting to contemplate whether it is a change in attitudes that has resulted in this improvement, or if it is the restrictions and fail safes that we have built in to construction that have achieved this.
- We spend a lot more time on pre-working these days and a lot less time actually building. It makes it even more difficult in many ways for contractors to work because there's a long lead-in time when they don't know if they've got the job or not. So they could have a massive peak in demand, or maybe they won't. We are still trying to sort that out today.
- One way in which we have gone backwards as an industry is that there is less muscle, less of a voice speaking out for the labour force these days. This is because of the way the industry has developed, the way it has moved responsibility for looking after the workforce downwards rather than upwards. The main contractors are not particularly interested; it is a concern of the subcontractors, but they are not so powerful and have less sway.
- Another loss to the industry is a sense of pride in engineering of itself, for itself. The same applies for tunnelling. Tunnelling used to be a sort of bug we would get, but it's an unfortunate situation that, with the best workload we've had in years (which is fantastic) suddenly everyone wants to be in tunnelling just because there are good rewards to be had. Not because they really like the buzz of tunnelling. It is still special, but I think it is becoming more just another part of civil engineering. Which I think is a shame. There is less interest in someone's opinion and judgement, and more concern as to whether they have signed a form."

7

The original number of London Bridge Associates after the departure from Taylor Woodrow's tunnelling division

At the start of the journey, the seven or eight major shareholders owned the whole company. Now 41 shareholders own a portion of LBA, but the non-majors own 51 per cent of the business. There are three major shareholders left.

Ibell adds: "A universal bonus is paid to all employees too. Everyone has a contribution to make, and if they are not then management is also to blame."

Distinct approach

An integrated approach, says Ibell, is something that some clients see the benefit of, while others do not. LBA likes to put people within client teams – indeed most of the company's work is within client teams – which allows a client to put together a top team, but not necessarily have to keep that team together at all times.

As for an offering; generally construction planning is considered LBA's specialism, at least among the engineers (while clients think of LBA as construction supervisors according to Ibell).

"We recognised a while ago that when you're doing construction planning, the first thing anyone wants to know is what it's going to cost. So you need to be able to put together a cost estimate. Now that is a very different skill to putting together a tender, and I think we have a unique way of doing it. It's gained us a lot of credibility and we often get asked in to either do the costs or check the costs.

"Basically it is method-based. As soon as we get beyond a very broad outline, we want to have the method there, and then we cost the method. You cannot just look at a similar job from 10 years ago and then slap some inflation on it, or adjust your costing based on length. You have to price the programme, the risks, the staff, the materials. It is not too difficult to price an amount of concrete, but getting the whole picture is more challenging.

Ibell says that a lot of people did not understand some of these ways of doing business in the early days, and that even today there are people who do not quite get them.

"Someone I know was looking at the HS2 costs, and made the comment that they were too detailed to be correct. Ironic. And when we were starting out, construction planning was a little method statement, which was then passed to a consultant who had done a little site work and a little site supervision. It was all very low key.

"But once we had done it a couple of times, clients started asking for it.

It does not matter if they understand it or not, it stands on its own; it is supportable. And when you get a discussion, as there has been on the Thames Tideway project, you have to justify every single point. And if you are wrong, the client and scheme can be in serious trouble. It is very important to be right."

Above: A visit to the Warwick University MSc course in tunnelling

Below: Channel Tunnel Rail Link Contract 240

THE FUTURE

Spreading into new areas or new disciplines is unlikely for the company; the leadership has decided what they are good at. As for where changes will come from, Ibell expects the development will come from developing CDM, fire safety, the usage of BIM and Tunnel Information Management (TIM). Specifically he expects improvements in the thinking around and the use of such tools, rather than development in the tools themselves (see reflections on industry box).

Ibell has hopes that new people, especially young engineers will continue to impress. But of the established hands, he says David Sharrocks, Harry Glennie, Terry Crabb, John Keys, Frank Ellis, Bob Allen, Simon Morgan, Ken Spiby, Steve Thompson and Dave Terry are all names that have really taken the company forwards. As for Ibell, he is winding down his workload, but not ready to retire just yet.

"I get to pick and choose the jobs I enjoy; which is pure consulting work basically. And helping the company internally where I can. Mostly I consult on insurance claims, or anything else that really gets the mind going and you can pass off some of your experience.

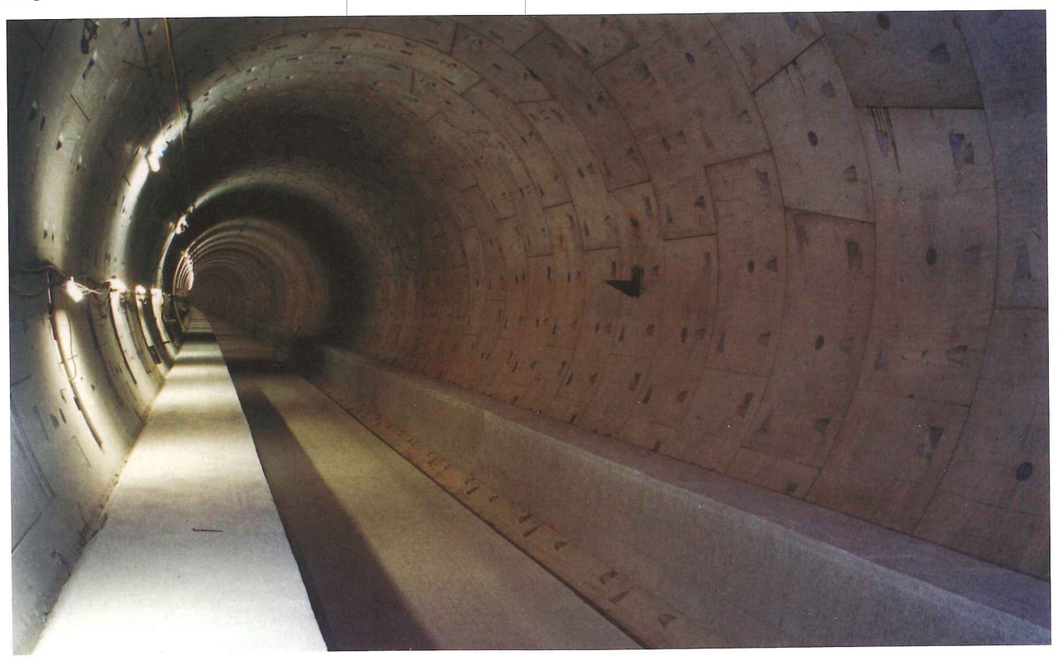
"At this stage in a career, when a problem comes along you tend to understand more of the issues behind it, you recognise other problems that you have wrestled with in years gone by; you have seen things that work well and things that haven't, and you can bring that experience. That is what I enjoy"

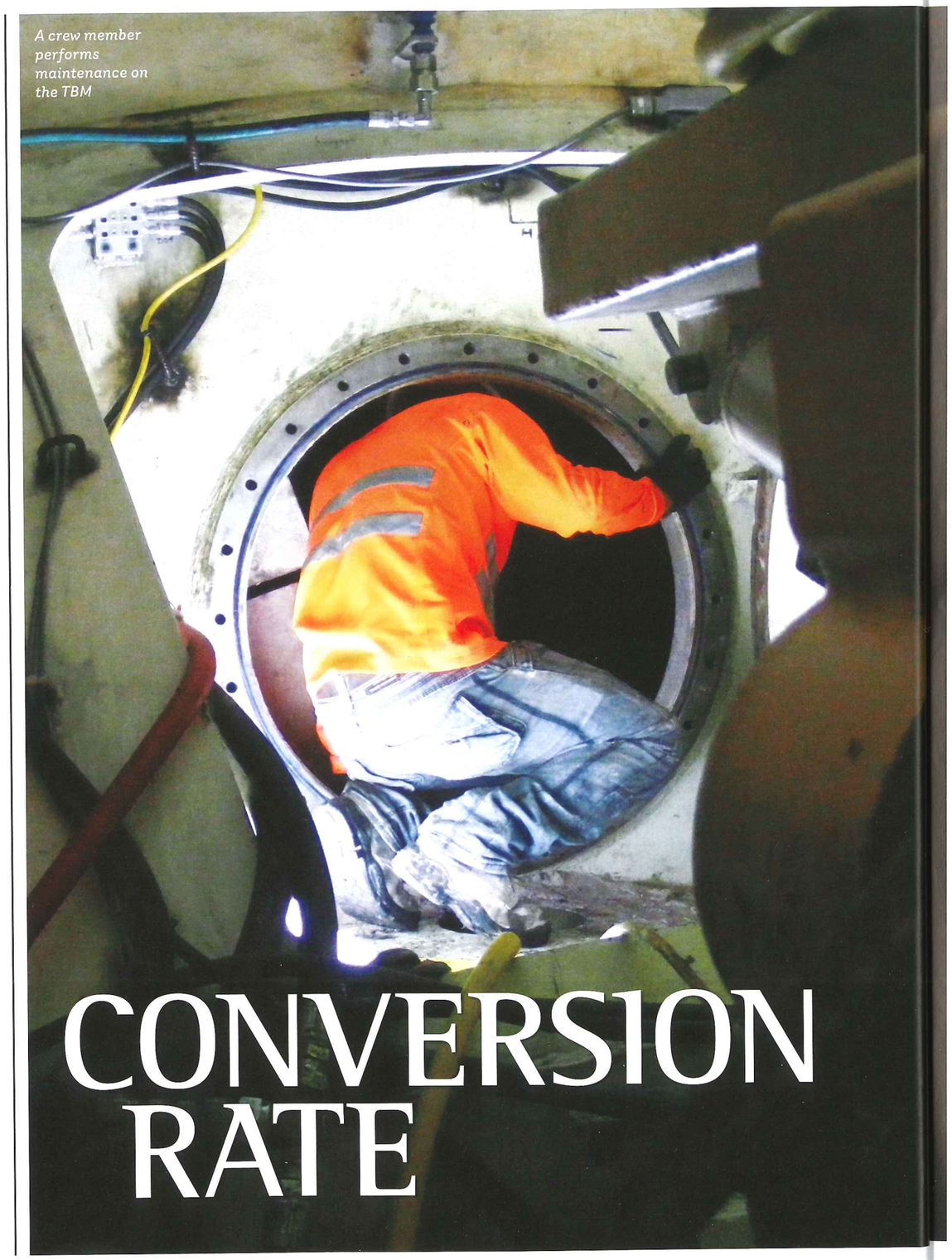
Advice for young engineers

"At one point in my career, I suddenly had a moment of understanding. A realisation that I could make a difference, and that people will listen to me if I have something to say.

"How do you have something to say? You have to read, to learn, to think about a comment yourself so that when it comes up you have something informed to say. If people sit in silence they never learn and never contribute.

"And listen to people who have an opinion. I stood up in Taylor Woodrow and said: "we have to change or we are in trouble". And sure enough a year later we were in trouble. That situation stuck with me."





A crew member performs maintenance on the TBM

CONVERSION RATE

Adding capacity to the over-tasked wastewater system in Mexico City, an alignment through changing ground conditions is a likely candidate for *Robbins'* Crossover TBM, **Nicole Robinson** reports

IN THE mountains northwest of Mexico City, the soft rock is self-supporting and very consolidated, a dream to mine.

"Even the face is self-supporting," says Roberto Gonzalez, Robbins' general manager in Mexico. "You could use a normal backhoe and excavate like that. It's a beautiful ground to bore."

But the alignment crosses valleys of tuff, faults and finishes with a stretch of soft ground with low cover. This is the scenario for Túnel Emisor Poniente II (TEP II), or the English translation of West Drainage Tunnel II.

Conagua, Mexico's national water commission, is building the 5.9km-long tunnel with a 7m i.d. to reduce flooding in the area, and increase wastewater capacity. Across three municipalities, some 2.1 million people will benefit from the tunnel project.

The contractor joint venture of Aldesa, Proacon and Recsa chose an 8.7m diameter, dual-mode type machine capable of "crossing over" between rock and EPB. With the August 2015 TBM launch on TEP II, manufacturer Robbins has supplied its first Crossover machine in Mexico.

END GAME

The manufacturer draws comparisons to the Kargi Kizilirmak hydroelectric project in Central Turkey. The design of the TEP II machine was based largely on experience from past projects, and that TBM in particular. Initial reports on the Turkey project showed fractured hard rock. Robbins explains, within 80m of launch the geology became substantially more difficult than expected, consisting of blocky rock, sand, clays and water-bearing zones. The machine required multiple bypass tunnels and major modifications before it could resume excavation.

Modifications included a custom-built canopy drill and positioner for enhanced drilling and ground consolidation, gear reducers to adjust torque and RPM to changing ground conditions, and short stroke thrust jacks to double total thrust capabilities. Robbins says these modifications proved instrumental to the design of its Crossover TBMs, including the TEP II machine.

In Mexico, the contractor JV expects to convert the machine from hard rock to EPB mode due to changing ground conditions in the last kilometer of the alignment. "Initially the proposal was a hard rock machine but they found they have 800m of water—more EPM conditions—that's the reason we proposed a Crossover," explains Javier Alcala, job site engineer for Robbins on TEP II.

The ground conditions at TEP II are complex, from competent to weathered volcanic rock to clay, and sand. "The geological profile of the project goes through six different types of lithology, and among them are the hard rocks, such as dacites, and tuffs with low overburden," says Aldesa's Enrique del Castillo.

"Besides going through several different ground conditions, the most important will be going through the Barrientos fault, as well as preparing the machine for going through the tuff that is found in the 800m at the end of the project," Castillo says of the project's geological challenges.

The final 800m is also the portion of the alignment with the lowest cover, some 12m, and the most populated. This is one of the reasons for using a Crossover machine. The rest of the drive has between 50-60m of cover on average with some stretches up to 150m.

"We try not to convert unless it's completely necessary because you stop, you have to drain the screw conveyor inside the machine, and you have to make a lot of changes, for example on the cutterhead," Robbins' Gonzalez explains, further outlining the changeover:

First, there are removable plates that increase the percentage of the cutterhead that is open; 20in disc cutters are swapped out for 9in soft ground tools; a rotary union is installed to supply additives and foam at the cutterhead; and then the screw conveyor is extended at the bottom.

While boring in rock the machine has a single direction cutterhead, and the capability to be bi-directional once in soft ground.

As an open mode machine boring in rock, the TBM is equipped in the event of entering running

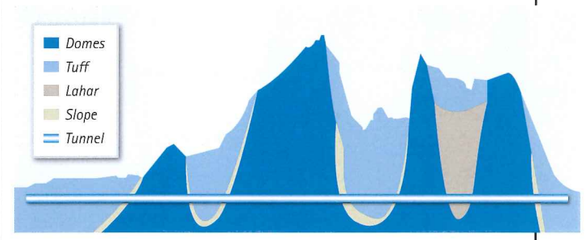


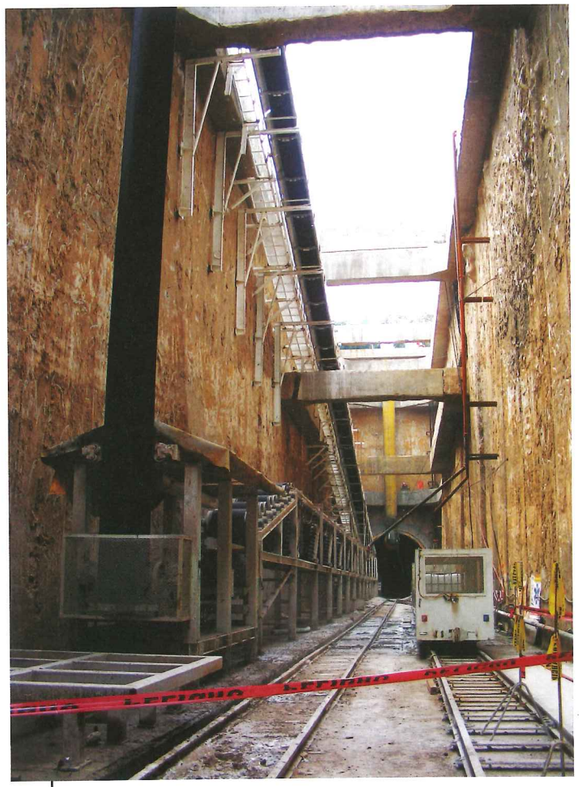
Table 1. Ground conditions

Colour	Descriptions	Meters
Domes	Large lava structural bodies with cauliflower structure and dactic composition. The rock is hard, fluidal, mostly healthy, but sometimes brecciated and rarely somewhat altered. Has suffered overall cooling fracturing and tectonic, thereby throwing an RQD through 50 to 60 per cent, but generally good recovery of 70 to 80 per cent.	3,745
Tuff	Pumice Sequence eruptions. Formed an important thickness of sandy particles moderately consolidated and horizontally stratified.	1,814
Lahar	Pyroclastic deposits gaps in sandy matrix; form powerful bodies of medium to good consolidation.	250
Slope	Chaotic sequence of blocks and gaps in matric of sand and tuffs, silty clay and paleosoils.	280

Source: TEP II

***Above:** The tunnel alignment passes through changing ground conditions*

Nicole Robinson
Editor of *Tunnels and Tunnelling North America*
Nicole is based in Minneapolis, Minnesota



ground, he says.

"These closure doors are able to maintain the material in the cutting chamber. They're just a safety."

It's not expected to be necessary in first portion of the alignment where most of the ground is andecite. In smaller valleys of tuff there is potentially some water, but it's unknown for now, he explains.

"For these cases we believe that these closure doors will be held to see what we have to do with the material, if we have to consolidate in the front."

The machine has two types of drills, shorter drills to inject an umbrella in the front, and a rear-mounted drill to probe the material in the front, and inject grout if necessary.

Another feature is multi-speed gear boxes. "On this EPB you will need more torque, less sped from the cutterhead so in the end we have a two-stage gear reducers: the gear reducers for rock, in which the cutterhead is able to go almost to 6.5 revolutions per min, and then we can engage the other reducer to be able to have a higher torque and less speed." Gonzalez says. "For example we are going to be rotating at 2.5 revolutions, more or less, with a lot more torque."

Above: The launch shaft and continuous conveyors

Below: Segments ready for installation at the job site

TUNNELLING

Aldesa's Castillo says one of the biggest accomplishments on the project thus far has been organising the logistics in such a small work space—fewer than 10,000m². The JV excavated a 30m deep launch shaft supported by 800mm-thick Milan walls (slurry walls), and used on-site first time assembly, he says, to start excavation as soon as possible.

Once assembled by gantry crane, the machine bored 100m before adding back gantries. When completely assembled the machine has nine gantries for a total of 1,030m length.

At the time *Tunnels & Tunnelling* visited the project, the crews were still adjusting to having the full machine in operation, and had only recently started using the continuous conveyors for muck.

The TBM was mining through a transition zone between tuffs and dacites, and had excavated 435m by mid November 2015. Project estimates call for an average of 15 rings per day.

At the time of publication the TBM has bored 1,417.5m, which equates to 945 rings. The best day has seen an advancement of 42.8m and the best week is 185.1m. Robbins' Mexico office reports the TBM has reached softer geology and is boring very well.

Tunnelling is expected to finish within this year and a second lining of reinforced concrete will be installed following excavation to extend the life of the tunnel

"Once we arrive to the final bit, it's a very close curve of 400m radius," Alcala explains.

The tunnel alignment ends along the rivers of San Javier and Xochimanga in Atizapan de Zaragoza, and from there the TBM will be extracted from the shaft following the curve.

"The Robbins conveyors have that advantage because they have these structures that can move according to the curve," he says. "They are not fixed. It's easier to control the curve of the conveyor system."

The JV is using continuous conveyors for spoil removal, with structure and cassettes supplied by Moldequipo Internacional. Presforza, located in Puebla, Mexico, is manufacturing the steel-reinforced segments for the initial lining

TURKISH LESSONS FOR TYROL

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

Tunnels and Tunnelling visits the Gemeinschaftskraftwerk Inn hydropower project in Tyrol, Austria just as access tunnel construction has been completed and one of two TBMs has been moved to the face. The manufacturer claims that lessons from the Kargi HEPP have driven improvements for this type of project

THE STATE of Tyrol in western Austria is the setting one thinks of when thinking of the Alps. Sharply rising mountains either side of an emerald valley, streams of water turned pale blue with minerals, traditional cowbells clunking as the animals move in small herds. The energy demands for the region are growing however, and to stay environmentally friendly a new hydropower scheme has broken ground. The Gemeinschaftskraftwerk Inn (GKI) project is owned by Austrian (86 per cent) and Swiss (14 per cent) business interests. It will provide electricity for approximately 100,000 homes in a region with a population of around 700,000.

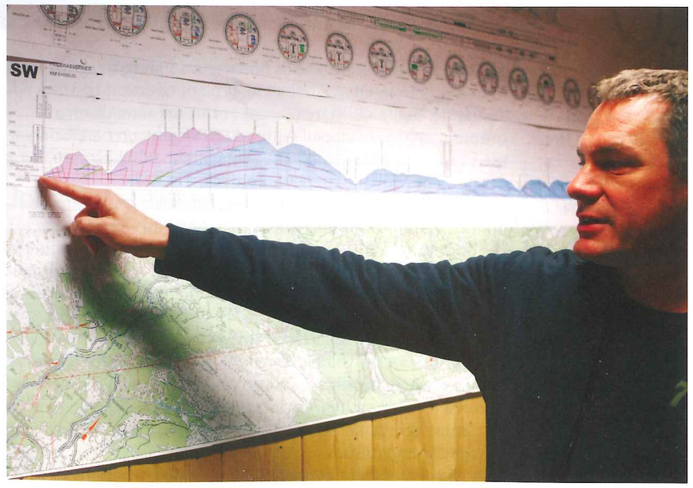
SCOPE

Contractor Hochtief selected two identical 6.53m-diameter Robbins double shield TBMs for the job. Tunnelling work is needed to construct a headrace tunnel just under 22km long and 5.8m in diameter. This will be constructed by a 12.1km southbound drive and a 9.4km northbound drive. The tunnel will transport 75m³ of water per second from a 15m-high weir down to a pressure shaft, which will drop down to turbines in a powerhouse. It is expected to come into operation in 2018.

Drill and blast access work

Although TBM technology has been selected for the main drive, drill and blast excavation up to 80sq.m was used to excavate a curved access tunnel that ends in a cavern (for a total 800m length of excavation) and then the 20m southbound TBM's launching stub. Running parallel to the tunnel back towards the north is another 20m stub tunnel, which at the time of Tunnels and Tunnelling's visit in October was waiting for the second TBM (a four-month gap between machine launches was in the schedule).

Two access tunnels were originally intended, but due to scheduling concerns this single access excavation was proposed to the client according to Hochtief project manager Stephan Assenmacher. Equipment used for the drill and blast phase included a three-boom Sandvik Axera T11 rig, a Liebherr excavator, two Liebherr wheel loaders and a Meyco Potenza sprayer. Girders and mesh were required in early challenging locations, which was reduced to just the plastic fibre reinforced SCL.



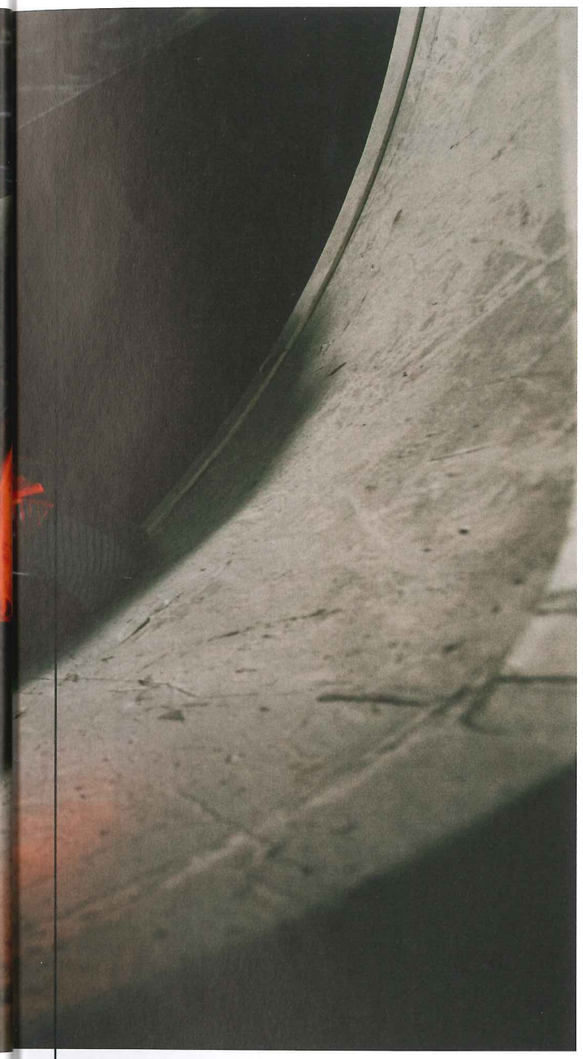
Below: The Tyrol region is close to the borders of Italy and Liechtenstein

TUNNELLING CONDITIONS

Geology is expected to primarily consist of 70MPa schist at up to 2,000m overburden and there are two fault zones expected. Squeezing ground is one of the major concerns according to Robbins field service technician Andy Birch; the machine can overbore by 25mm. In really extreme cases this can be extended to 50mm, but work would be required to lift the main bearing if this level of overcut is ever needed. There is also an emergency break out

Project facts

Name: Gemeinschaftskraftwerk Inn
Location: Tyrol, Austria
Contractor: Hochtief
Purpose: Hydropower headrace
Methodology: TBM
Finished diameter: 5.8m
Length: 22km
Geology: 70MPa Schist



thrust of 57,000kN at 450 bar in case of squeezing ground.

An older style of gripper system has been put in place in for these machines according to Robbins field service engineer Miguel Panteghini. Instead of horizontal opening, the grippers open vertically but with an angular tendency. They need good rock but allow more space inside the machine "this feels like a larger machine to work in," adds Panteghini. In poor conditions, the machine may run in single mode.

LINING

The tunnel is lined with cage-reinforced precast concrete segments in a 4+0 configuration, unbolted and unsealed. Hochtief has reportedly had bad experiences recently with fibres and so prefers cages. Concrete is from an onsite batching plant operated by Hilte and Jehle. Some 48 Herrenknecht Formwork moulds on a carrousel system equipped with a 55°C steam curer are being used to cast the segments. The segments themselves are designed by Vigl and are 270mm thick, 1m wide.

Above: ***Inspection work inside the first TBM to reach the worksite***

Top right: ***Some 48 moulds were used to manufacture segments for the 4+0 lining***

Segments are supplied to the machine via a multipurpose train consisting of four segment cars, one miscellaneous car, two for pea gravel, 10 for muck and one locomotive. California Switches allow additional muck cars to be on standby near the machines to keep a good advance rate going.

MUCKING AND ENVIRONMENT

Excavated material will be stored on site and used for lining purposes where possible. This is to reduce the amount of material requiring transport by road. Unsuitable material will be transported by an Agir conveyor from the portal to on site storage for later disposal.

A client statement added: "An important aspect when storing the excavated material is [...] the possibility of returning the area to agricultural use after the completion of the construction work. For this reason, the fertile topsoil is removed and stored so it can be put back in place. Subsequently, the area covered by the storage area will be replanted."

JOURNEY TO THE FACE

The machines were manufactured and assembled (one partially, one full) at the factory in Narni in Italy. They were shipped 800km, a journey that took in the Brenner Pass. According to Andy Birch, there were a few abnormal loads in terms of weight, but the bulk of physical size of the loads was not a particular concern. The cutterhead were manufactured in two pars and welded on the front side. This should also make the machines fairly easy to disassemble and remove from the tunnel when the job is done, says Birch. When moving the machine to the face, locos synchronised by one operator (in terms of power and revs) pushed the machine while it was being pulled by an excavator. Specialised transport dollies, articulated by a spigot and pin carried the machine.

LESSONS LEARNED

Martin Rauer, project manager for Robbins Europe said that lessons had been learned from the Kargi hydroelectric power plant: "Grout injection techniques, forepoling, peripheral shield lubrication, water inflow control and a large overcut capacity. That is basically what we have taken from earlier work. Essentially bringing NATM principles to TBM technology.

"At Kargi we implemented a canopy drill to allow pipe tube support, increased the torque by 50 per cent, and the advance rate doubled"

Machine specification

Diameter: 6.53m
Manufacturer: Robbins
Cutterhead: Hard rock, back-loading, designed for fractured ground
Cutters: 41 no. 17-inch Wedgelock discs
Maximum thrust: 40,712kN at 450 bar
Maximum torque: 6,081kNm at 0-5.4 RPM
Cutterhead power: 2,310kW
Cutterhead speed: 0 to 8.7 RPM
TBM weight (with backup): 1,160t

MEETING THE CHALLENGE

A small engineering company in Essex is making a big contribution to Europe's largest infrastructure project, Crossrail. **Sally Spencer** reports

CROSSRAIL, EUROPE'S largest infrastructure project, will connect 40 stations across Greater London and sees the construction of 10 entirely new stations, the scale of which travellers have not seen the like of in the UK.

Crossrail station platforms will be 250m in length in order to accommodate the new 200m-long trains that will pass through from the outset and enabling 240m-long trains to operate in the future as passenger demand increases.

PLATFORM SAFETY

As around 200 million passengers are expected to travel on Crossrail each year, safety is paramount and one of the key safety measures is the installation of platform edge screens (PES) at the stations.

Knorr-Bremse Rail Systems UK's platform screen door system – 4km in all – is being integrated with the PES, which will sit above, bolted in to the crown of the tunnel to fully enclose the platform.

In five of the new stations, Tottenham Court Road, Bond Street, Liverpool Street, Farringdon and Whitechapel, where sprayed concrete forms the platform tunnel linings, the bolts that fix the metal framework that holds the PES in place are being supplied by Excalibur Screwbolts, an innovative SME based in Essex.

You may be able to count the number of Excalibur Screwbolts' full-time employees on the fingers of one hand but its relatively small size hasn't stopped it from becoming a leading name in the sector and a go-to company for major infrastructure projects, including tunnelling.

In fact its patented and apparently unique twin helix thread bolts have been used in landmark projects such as the Gotthard Tunnel and the Channel Tunnel Rail Link (CTRL). One legacy of the latter project in particular, was the call to supply Crossrail.

DESIGN LIFE LEAP

With many engineers and project managers migrating from CTRL to Crossrail, the company's name was front of mind but the contract wasn't a foregone conclusion. CTRL had called for a design life of a mere 25 years, whereas Crossrail was specifying 120 years.

Fortunately, however, Excalibur Screwbolt was ahead of the game in

***Below:** Platform Edge Screen brackets are securely held in position by Excalibur M20 studbolts*

Sally Spencer
Sally joins the Tunnels and Tunnelling team as a contributing editor this year

developing a product with greater longevity.

"Standard European Technical Assessment-approved fixings have an estimated design life of 50 years, so 120 years might have seemed a tall order," said Jim Clement, technical manager. "However, we had already developed a new and revolutionary Screwbolt PLUS, which has extremely high levels of corrosion resistance.

"Prior to this our standard surface finish comprised electro-zinc plating with a passivation and we were often asked if we would produce high-grade stainless steel screwbolts," said Clement.

"For technical reasons, we considered this wasn't suitable for the Excalibur Screwbolt so we embarked on our own intensive development programme to find a unique new process of corrosion resistance for our entire range of products.

After a period of in-house trials and performance testing, Excalibur Screwbolt PLUS was born."

TESTING PROCESS

Rigorous testing followed, including at Ford Motor Company, which carried out a nine week accelerated cyclic corrosion test on the Screwbolt PLUS. It passed with flying colours – in fact, it performed significantly better than the high-grade stainless steel alternatives that were subjected to the same tests.

Other testing, at SGS MIS Testing Ltd, demonstrated that Screwbolt PLUS survived 6,200-hour salt spray resistance testing – a dramatic improvement on the 1,000-hour salt spray resistance afforded by the standard mechanical zinc finish screwbolt.

"This data supports the technical opinion that the Screwbolt PLUS will last in excess of 120 years," said Clement. "It's a great leap technologically and it takes our screwbolts' performance to another level.

"This technological advancement in corrosion protection substantially increases the whole life expectancy of an anchor in the harsh environmental conditions associated with tunnels," he continued.

"In practical terms, removing the need for replacing less robust anchors at regular intervals means that maintenance and renewal costs are greatly reduced."

*Above: **Platform edge screen brackets after adjustment for line and level***

*Below: **Steelwork in position; GFRC panels can be placed***

It was around the same time that Crossrail came calling with its contract for mechanical fixing (it didn't want to use resin fixing) into the crown of its SCL platform tunnels. As well as the requirement for a 120-year design life, the bolts also had to be long enough to cope with the sometimes-variable thickness of the SCL.

As a result, and in collaboration with Atkins design consultancy, Excalibur Screwbolt developed a 420mm-long, 20mm-diameter screwbolt.

Even at this point the contract wasn't in the bag as Crossrail then carried out its own exhaustive testing.

STATION MOCK-UP

In order to develop and test designs for the underground station platforms, Crossrail created a life-size mock-up measuring 20m in length, 10m in width, with a ceiling height of 5m above the platform-edge doors. It also contains a 4m long side-tunnel entrance providing entrance and exit.

Crossrail also commissioned Imperial College London's Department of Engineering and Vinci Technology to put the Screwbolt PLUS through its paces in order to ensure it could withstand the relevant stresses and strains involved with the designated design life into the SCL.

Tests conducted included tension and shear tests, cyclic tension and shear tests and mock-up simulation tests to top and side connections.

"Screwbolt PLUS has now gone through one of the most arduous testing regimes possible, well beyond normal testing," said John Stevens, sales manager.

The results, contained in a confidential 55-page report, were apparently positive, leading to the Screwbolt PLUS being added to the Crossrail design specification.

The contract calls for several thousand screwbolts for each of the five station platform tunnels. The base product is produced in Poland using high-grade steel obtained from within the EU and then the majority of the work – the hardening and surfacing operations – is carried out under license by two third-party manufacturers in the UK.

*Below: **Once installed, a percentage of studbolts are proof tested to a pre-determined tensile load***

INSTALLATION

Installation work has progressed smoothly. At the time of writing, the main metal work had gone in at Tottenham Court Road and Bond Street and work was starting at Liverpool Street.

"The two contractors we've been working with so far, Laing O'Rourke and Costain Skanska JV have been happy with the speed at which they've been able to progress," said Stevens. "We assisted by being on site and helping the contractors as much as possible but once they had set themselves out it was very straightforward."

He added that one of the benefits of a screwbolt is that, should the need arise, it can simply be unscrewed and relocated.

That wouldn't be possible with an expansion anchor or resin anchor without damaging a prime asset – the tunnel lining.

"Crossrail has put the bar higher than it has ever been before so we'll have to wait and see if other projects want to match it," said Stevens. However, looking ahead, Excalibur Screwbolts is confident that its PLUS product will find favour as a cost-effective alternative to high-grade stainless steel fixings in other tunnel projects.

"We're very proud to be associated with Crossrail and we hope the spin-off from this will be the development of our product within the tunnelling industry nationally and internationally," added Clement.

"As a small company our policy has been to try to keep one step ahead of the competition and the only way to do that is to think laterally and be brave enough to do something different," he added.

"I believe that this is what we have achieved with this product and what we have achieved as a company. We believe the potential for this product to expand into other contracts on a worldwide basis is significant.

"We have shown what strength British companies have in the development and innovation of new products," said Clement. "And, in so doing, we've been able to provide a solution to a problem on a landmark British project"

CAISSON AND SHAFT CONSTRUCTION

Andrew Smith, contracts director for *Joseph Gallagher*, deals with the construction of shafts and caissons using precast segmental linings together with the use of SCL in shaft sinking operations. Commentary is also given on design considerations for the construction of such structures

SHAFT SINKING in the UK is generally carried out using circular pre-cast segmental linings, originally developed after the war as an alternative to the original and more expensive cast-iron linings. They are typically used to provide access for tunnelling operations where they can then be converted to permanent access chambers. More recently, they are increasingly being used to form storage chambers and pumping stations etc where they can offer a cost-effective solution to more expensive alternatives such as in-situ construction within a piled cofferdam. The advantages are that the permanent works materials are, in effect, used as the temporary works during construction and also that the construction 'footprint' is kept to a minimum (an important consideration in urban areas).

Specification clauses for shaft construction and break-outs from shafts can be found in the BTS Specification for Tunnelling (2010).

Andrew Smith
Andrew has worked for over 50 years in the UK Tunnelling Industry

For small-diameter shafts in the range up to 4m, full-circle segmental rings are available but high unit weights need to be considered when specifying the construction plant required.

As circular structures, segmental shafts normally require no additional bracing during construction since all the ground loads are evenly distributed to produce only compressive loads in the lining. Another advantage is

Below: Oruga shotcreter and tunnel opening. *PHOTO: MEYCO-BASF AND JOSEPH GALLAGHER*

that, properly constructed, the risk of settlement is kept to a minimum; the construction process should ensure that the exposed ground is supported with the minimum of delay and there are no large temporary working spaces to be backfilled on completion.

Precast shaft linings were originally designed to mirror the earlier cast-iron linings so that they had a rib and recessed panel appearance. As such, they had a limited use in the context of depths exceeding around 20m and are no longer readily available. These linings have now been replaced with solid units, normally 1,000mm wide, in standard diameter ranges from 4m to 25m with different manufacturers having their own bolting systems. The individual segments are cast to very exacting tolerances to ensure accurate alignment between components. The design of these units normally incorporates a sealing system utilising hydrophilic strips or rubber gaskets, the latter being factory fitted. Increasingly, these segments are being manufactured using fibre reinforcement which has a beneficial effect in terms of fire resistance and also makes it easier to break-out openings and attach fixings. Although the majority of manufacturers produce a standard range of products to a set design suitable for the vast majority of projects, they will also provide a design service and special manufacture of linings to suit more demanding or specific design conditions. Additionally, as part of their service, manufacturers are able to provide specialist items such as corbel units to accommodate landing slabs and also complete roof slabs designed to the engineer's loading requirements.

A more recent development, often used in conjunction with segmental shaft construction, is the use of sprayed concrete lining (SCL). SCL is used to replace the segmental lining and can be used in conjunction with reinforcement and/or lattice arches or, alternatively (and now more commonly), with fibre reinforcement. Typically, segmental ring construction might be used for the upper levels of the shaft where ground conditions and surface features make this appropriate with a change to SCL in the underlying more stable strata. For permanent works, use of a secondary in situ lining may be required to create a smooth finish. SCL can be used in conjunction with either sprayed-on or sheet-membrane waterproofing. One considerable advantage with SCL is that openings etc required in the shaft lining can be formed by the use of additional framing reinforcement but without the need to introduce expensive temporary works support while the portal structures are constructed. On the other hand, openings in shafts built with segmental rings generally require considerable temporary support during construction (particularly at deep levels) as the inherent compressive strength of a shaft ring is lost once an opening is formed in it, until the permanent works are completed.

MAJOR ALTERNATIVES

Alternatives to shaft sinking methods that are not covered in this article include sheet piled cofferdams, diaphragm walls and contiguous and secant walls. For information on these methods, please consult the full publication (see box, p.44).

Common methods of construction

Shaft sinking methods are broadly subdivided into two categories: underpinning and caisson sinking. See the BTS (2004) publication, Tunnel Lining Design Guide, for more details.

Underpinning

Underpinning involves the excavation and erection of each ring of the segmental lining beneath the previously constructed ring. As each ring is completed, cementitious material is injected behind the lining to fill any voids and secure it in the ground, ready to support the next ring which is bolted up from beneath. Different manufacturers have their own bolting systems to do this. This method is normally used in firm self-supporting ground or where ground treatment processes have created stable ground conditions. However, it can also be used to recover a situation where a shaft being sunk as a caisson has become stuck although additional ground stabilisation processes will probably be required in this situation.

The initial segmental ring is placed in a pre-dug excavation and keyed in to a concrete collar cast around it, normally by inserting dowels through the grout holes. It is vital during this process that this initial ring is built within the correct tolerance and fully supported, as any settlement during the casting of the collar could have serious repercussions in keeping the rest of the shaft vertically aligned. Once the first ring of the shaft is fixed in the ground, it is common to fix plumbing brackets around the top of the ring to check verticality as the shaft is sunk.

The grouting process requires the base of each ring to be sealed. There are geotextile hoses available that can be fixed behind the ring before it is built; after building, the hose is inflated with grout to seal the annulus before void grouting begins. It is however more common to push excavated material in under the ring once built to achieve the same result: so-called 'fluffing up'. When using this method, care must be taken not to damage the seals. If an excavator is being used it is possible to fit a purpose-made blade for this purpose. It is also good practice to form small voids in the previously grouted annulus up to the grout holes of the ring above to release any trapped air as grouting takes place.

Excavation of shafts constructed by underpinning is commonly carried out by 360° excavators initially working from the surface and then lowered into the excavation as it becomes deeper. Alternatively, there are a range of pole grabs available (some telescopic) that can be attached to excavators and used from the surface. With the advent of zero tail swing models, it is possible to get machines into all but the smallest shafts. It is very important to accurately trim the excavation to the correct profile; this avoids overbreak and excessive grout use.

Traditionally carried out by hand, adherence to current HAVS (hand arm vibration syndrome) regulations can make

this a time-consuming process. One method of overcoming this is to reverse the bucket on the shaft excavator so that it can dig upwards to assist the trimming process. Segments are usually placed by crane using specially manufactured underpinning frames, supplied by the segment manufacturers. Grouting normally uses bagged cementitious material supplied shrink-wrapped and on pallets for weather protection and ease of handling by forklift. It can be mixed and pumped in special composite units driven by compressed air. The segment manufacturers generally provide threaded grout sockets in their segments, and it is important to check that the grout gun nozzle is compatible with the fittings supplied.

As well as underpinning using segments, the same basic process can be used with SCL methods. Once the shaft has been excavated for the pre-determined length, the SCL is applied using either a hand-held nozzle or a robot sprayer. For most operations, this material is supplied ready-mixed and either discharged directly into the pump or held in a re-mixer on site. As with most operations involving SCL, the material is supplied retarded and an accelerator is added at the nozzle. Reinforcement can be provided in the form of mesh or pre-fabricated arches, but it is becoming increasingly common to use fibre-reinforced concrete which speeds up the process considerably. Openings typically use steel reinforcement locally, and can be formed incrementally as the excavation proceeds without the need for temporary support. If required, sprayed waterproof membranes can be incorporated into the lining, normally by sandwiching them between two separate layers of SCL.

Caisson sinking

Caissons can be round, square or rectangular but must be of a regular cross-section with no protrusions which would cause drag leading to the danger of lock-up. The majority of caissons are circular, however.

Caisson sinking typically involves constructing the first one or two rings of the shaft at ground level within a substantial reinforced concrete collar using a special cutting ring at the leading edge. As with underpinning, it is vital that the initial rings are built accurately and held in position while the collar is concreted. These rings are surrounded by polystyrene sheets before concreting the collar to create a sleeve through which the shaft can

***Top:* Underpinning showing trimming.** *PHOTO: JOSEPH GALLAGHER*

***Above:* Steel cutting edge (during trail erection) ready to receive pre-cast units.** *PHOTO: PL MANUFACTURING*

slide. Sacrificial jacking bases are also positioned before concreting within the collar onto which the shaft jacks are then fixed. For shaft sizes up to around 10m diameter, most segment suppliers manufacture their own precast cutting edges. Over this size, it is necessary to use a fabricated steel unit which must be designed to suit the sizes and fixing patterns of the rings to be used. For larger diameters and demanding ground conditions, it is essential to have a steel unit which can be welded on site to increase rigidity and prevent shaft distortion during sinking.

The cutting edge must provide an overcut to the rings to be used so that an annulus is formed as the shaft sinks, enabling a lubricant to be introduced. This annulus is typically of the order 50mm. There are a number of products on the market suitable for this operation. The caisson is sunk by excavating from within and then letting the shaft sink in a controlled manner, almost always by the use of vertical hydraulic jacks positioned around the collar. The size and hence weight of this collar must be sufficient to counteract the anticipated jacking loads required. As the shaft sinks further, rings are added at the surface with specially designed working cages needed for this operation.

Below: ***Lee Tunnel shaft with decks***

Bottom: ***Jacks pushing PC units down, with clam-shell excavator.*** *PHOTO: JOSEPH GALLAGHER AND SPECIALIST PLANT*

The annulus created by the cutting edge is kept filled with a thixotropic material such as Bentonite or one of a range of synthetic products currently available to support the excavated ground and to minimise friction. On completion of sinking, this material is replaced by the injection of cementitious grout in one operation to lock the caisson into position and to replace the lubricant with solid material to minimise settlement. During sinking, a constant check must be kept on the verticality and square of the shaft and corrections made on the jacks to keep it within tolerance.

Once a caisson becomes badly out of alignment the consequences can be severe, including getting it stuck and/or segment damage. In this regard, careful attention should be paid to the lubrication process, particularly where there is a risk of ground coming onto the caisson. In addition, a careful analysis of the ground conditions should include a determination of the likelihood of large obstructions such as boulders blocking the cutting edge. Caissons have far less danger of becoming stuck in fine-grained homogeneous soils than in, say, gravels or boulder clay, where alternative methods might be more appropriate.

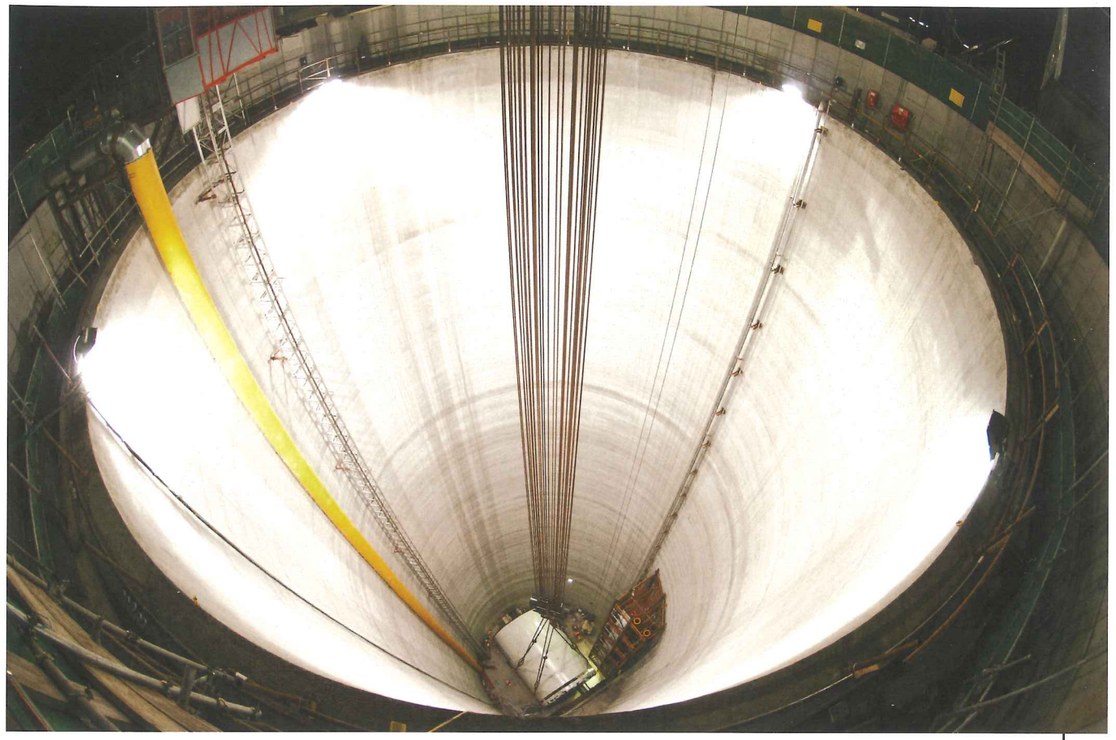
Caisson excavation can be carried out 'dry' or 'wet' depending on ground conditions. If the ground is naturally stable or has been stabilised by, for example, dewatering, excavation can be carried out from the surface or from within the shaft using excavation plant described for underpinning above.

If the conditions are unstable and/or waterlogged, or where the hydrostatic conditions could cause the base of the excavation to 'blow', excavation must be carried out with the shaft flooded to the prevailing hydrostatic level. In these circumstances the excavation plant normally used is either an excavator-mounted pole grab, where special telescopic models can reach depths of around 20m (see image below), or a rope-operated digging grab mounted on a crawler crane. With the latter, the digging ability is governed by the hardness of the material and the submerged weight of the grab. In hard material it is possible to add weights to the grab; if this is not successful, measures such as pre-auguring or the use of chisels suspended from the shaft crane must be considered.

It is becoming more common to use caisson sinking, even in stable ground, because the method eliminates the need for the trimming process required when underpinning. The method also minimises the need for personnel to be in the shaft, as the ring building takes place at the surface.

The same plant is used for mixing and pumping the lubricant as for the final grouting.

With wet caissons it is normally necessary to seal the base with the shaft submerged. This is because dewatering, once the shaft has reached its depth, might cause the base to heave or 'blow' under hydrostatic pressure. Even if dewatering is



a possibility, sealing the base in wet ground conditions can be extremely difficult. The depth of the so-called concrete 'plug' must be sufficient to provide enough resistance to the hydrostatic uplift in conjunction with the weight of the shaft rings and the weight of the collar. The latter is normally attached to the shaft, once sunk to its final position, by fixing dowel bars through the top rings into the collar designed to provide the shear resistance required. The concrete plug is placed by tremmie methods, almost always using concrete pumps. To provide a key it is usual to install recessed panel rings in the plug location or, alternatively, corbel rings. Segment manufacturers usually supply these as part of their shaft segment range. The plug must be left in place for a minimum of five days to cure before dewatering begins. Preparation of the surface can then commence, usually by placing a regulating blinding, to allow construction of the structural base above.

Current practice in the UK in calculating temporary resistance to uplift normally ignores any resistance provided by grouting the annulus or the shear resistance of the ground at the base, and usually assumes a groundwater level at ground level. On top of this, a safety factor of the order of 1.05 is typically applied.

Where the base of the shaft is founded in stable ground or it has been rendered temporarily stable by dewatering/pumping or another ground stabilisation process, as an alternative to a deep plug it is possible to provide uplift resistance by under-reaming. The shaft is first stabilised by normal annulus grouting and the cutting edge is usually removed, which in the case of a steel fabricated unit can be re-used.

The base excavation is then under-reamed, using temporary supports if required, to extend it beyond the shaft footprint. Once the reinforced concrete base is cast, this mobilises passive resistance of the undisturbed ground above the toe to counteract uplift.

Above: ***View down the Lee Tunnel shaft showing TBM. The project was undertaken by the MVB joint venture comprising Morgan Sindall, Vinci and Bachy Soletanche***

There are a number of ground stabilisation processes that can be used to aid shaft sinking and to reduce construction risks; these are discussed in detail (see full publication).

It is worth bearing in mind that if the shaft construction involves excavating, moving and disposing of large amounts of saturated material, particularly in urban areas, it may be prudent to consider ground stabilisation on environmental grounds to lessen the impact.

Likewise, if the shaft is to be sunk using sump pumping to control groundwater, the issues of silt separation and discharge facilities should be seriously considered; very exacting standards are normally demanded from licensing authorities before such discharges can be accepted into surface water disposal systems. If deep well dewatering is being considered, there are issues to be addressed with regard to abstraction and discharge licenses.

The use of such processes needs to considered and decided upon at the construction planning stage as installation is more difficult to achieve once construction has started, likely to be less effective and can be very

disruptive and costly.

Pre-cast roof slabs

Most shafts require some form of roof slab for the completed structure. As an alternative to costly in situ construction, often requiring expensive temporary formwork support, most shaft segment manufacturers will provide a pre-cast solution as part of the service they offer. This can also have the benefit of time savings as the manufacture takes place off site with the installation itself normally taking 1–2 days. The precast manufacturer will typically design the slab to the engineer's requirements as part of this service. However, the whole process normally takes of the order 8–10 weeks, so early planning for this option is advisable.

PRINCIPLES OF DESIGN

The design of a shaft, the method of sinking and the selection of the lining depend on many factors. Shaft projects can vary from small, simple schemes to large and complex systems, and the final use will affect the design.

The most important factor which influences shaft design is the type of ground and whether it is unstable or competent and self-standing when excavated. The presence of groundwater exacerbates the unstable ground conditions and imposes hydrostatic pressures which increase linearly with depth in both unstable and competent strata.

Once ground conditions are known from site investigations, the basic parameters for excavation and muck removal, groundwater control, ground stability control and lining installation can be evaluated and the shaft lining type chosen (visit http://www.alanauld.co.uk/index.php for more details). Calculation of active pressures from the ground on to the walls is covered in the full publication. These figures are also used to give upward pressures to check the stability of the base in the temporary as well as the permanent condition. Note that it is the situation before the base is installed that is the critical condition, and that particular dangers are created by the hydrostatic forces.

Structural design of pre-cast units follows standard reinforced concrete or fibre-reinforced design as appropriate, but is a service provided by the supplier.

Design of plan-circular structures in the ground is by using hoop compression, suitably factored to make allowance for non-uniformity of ground loading, and allows a very light efficient structure to be used. Openings in hoop compression attract very large concentrated loads around their edges.

It is always prudent to design out any plan shape with intrusions or a non-uniform cross-section, not only for the high stresses at angles but because of the danger of such shapes becoming stuck when being sunk as a caisson

Purchase the book

This article is based off a chapter which forms part of a book published by ICE Publishing. The full publication: *'Temporary works: Principles of Design and Construction'* is available from the ICE Bookshop for GBP 118 (USD 170) as *Tunnels and Tunnelling* goes to print.

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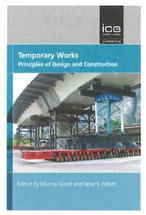

View from the base of the Lee Tunnel shaft

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KEEP ON RUNNING

The October 2015 meeting of the British Tunnelling Society also saw a presentation by **David Holland** of *Mabey* and **Kim West** of *Arup* on works relating to the Canning Town Flyover for Crossrail's contract C305

CROSSRAIL'S C305 CONTRACT is in the east of London with its tunnels, forming the G-drive, running from the Limmo access shaft to the Victoria Dock portal where they terminate. Canning Town is located just north of the River Thames and the structure of concern was the flyover that carries the Docklands Light Railway (DLR). The primary objective was to keep the DLR trains running while the G-drive TBMs passed beneath the area. It was important to complete the G-drive tunnels on time as track laying operations were to start from the Victoria Dock Portal, passing through these tunnels, working westwards into central London: any delay would have held up the whole Crossrail project.

The flyover (viaduct) structure is supported by piled piers along its length and is formed in three composite sections: a 50m long central steel deck which is bolted into longer concrete end-spans either side of it. The flyover is slightly sigmoidal in plan, with the steel deck spanning the point of inflection. The first westbound (WB) G-drive ran only just beneath the southern end of the flyover while the eastbound (EB) tunnel passed directly beneath a large proportion of the piers and so was much more challenging. Numerous bearings are incorporated into the flyover structure along with a fixed point in the central section and a movement joint at the southern end (denoted SA0).

As a consequence of its shape in plan, the bridge bows laterally as it warms up, an important aspect to appreciate in advance of the tunnelling works. Tunnelling was mostly in London Clay (and just into the Harwich Formation below it), a good tunnelling medium, although the nature of the London Clay in East London can sometimes be unpredictable and not as expected from the ground investigation boreholes.

Above: Section of Crossrail tunnel a short distance to the east of Canning Town

Opposite: Wallasea Island bird reserve will benefit from the spoil from Crossrail

Prior to starting the tunnel drives, various options were available to safeguard the flyover structure with varying degrees of risk and inconvenience: (i) close the DLR during tunnelling operations, providing an alternative bus service; (ii) proceed without any protection measures (e.g. jacking of the bridge piers and deck); (iii) control tunnelling-induced settlements using jacks; (iv) extend the length of engineering hours to tunnel only during this period to allow movements to be assessed before the DLR trains started running at the beginning of each day; and (v) provide some alternative alignment so the works would have no impact on the DLR. Option (i) would have been the safest and preferred Crossrail option but would not be popular with DLR or their customers. Realigning the tunnels, option (v), was not practicable. If sufficiently low volume losses could have been guaranteed then option (ii), to proceed without jacking could have been feasible but this was not the case. Extending engineering hours, option (iv), would have been inconvenient for both Crossrail and DLR. The option chosen was to tunnel after installing a controlled jacking system to be run in conjunction with a comprehensive monitoring scheme, option (iii). The choice was strengthened by the fact that it was possible to drive the WB tunnel first, which was expected to have a much lower risk associated, thus enabling instrumentation feedback and control systems to be tested.

PRE-CONSTRUCTION ANALYSES

Detailed appraisals and analyses were made to assess potential movements (at a range of volume losses) to assess acceptable levels of hogging, sagging, curvature and twisting

David Holland
David is the technical director for Mabey Hire, a leading supplier of non-mechanical plant hire

Kim West
Kim is an associate director for tunnelling at Arup. He has spent much of the last ten years working on Crossrail

in conjunction with the viaduct bearings (for both final and transient conditions). Each step had to be agreed between Crossrail and DLR engineers as even at a 1 per cent volume loss, predicted crack widths would exceed limiting values. Even with the jacking control systems in place there were still concerns about exceeding crack widths beyond 0.2 or 0.3mm which could lead to problems with long-term concrete durability.

After much discussion it was decided that rather than working to absolute tolerances it would be better to introduce a 'reference line' concept that would allow the flyover to tilt but without impacting on the structure. Twisting and bending of the structure were of greater concern and the instrumentation set-up was designed with this in mind: relative movements were assessed rather than absolute levels. It was also considered better to focus on slope measurements, rather trying to assess other variables such as bending and differentials between slope measurements, as confidence in overall control would reduce when many of the piers are moving together both vertically and horizontally. Therefore having good differential settlement rules was a practicable compromise.

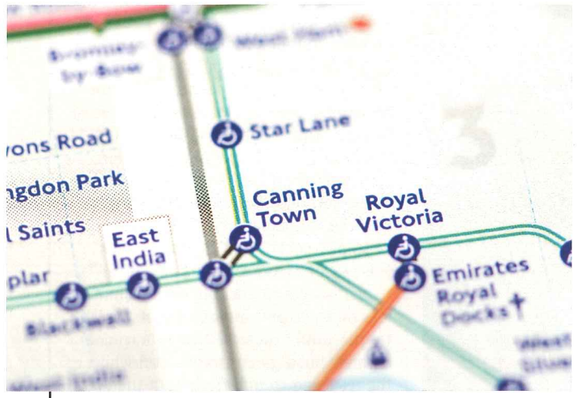
Apart from settlement and twist another consideration was the load on the bearings, especially the lateral ones. In the case of the latter, without horizontal jacks the loads would increase by an amount that would be difficult to quantify. The horizontal jacks were therefore considered necessary, especially at the southern movement joint SA0. Without this capability there was a risk of step-dislocation of the rails, which was essential to avoid.

Settlement predictions for a volume loss of 1 per cent indicated that the WB tunnel would cause settlements reaching a pre-defined green trigger level while the resulting trough from both the WB and EB tunnels combined, would cause settlements more than 30 per cent in excess of those assigned as the red trigger level.

The concept of considering relative rather than absolute settlements was tested in advance of the tunnelling by the ground movements induced by dewatering operations. A total of about 6mm was measured but as this occurred over a widespread area all the piers were equally affected and so the relative movements and their consequent impact on the flyover structure were negligible, despite the fact that the red trigger level was 5mm.

An assurance process using the Railways and Other Guidance Systems (ROGS) regulations was also undertaken, involving a number of steps to assess the level of risk the works posed. This suggested that there were significant risks that had to be dealt with, necessitating the Crossrail engineers to set up a system with their DLR counterparts to obtain sequential approvals for the various stages of works.

A methodology was implemented to model the response of the piled pier foundations based on the location of piles within the settlement trough. A depth of two-thirds the pile depth was chosen as a representative point: for the WB tunnel drive the pile groups of the northern piers were outside the zone of influence while some of the southern pier pile groups were just inside. Much greater interaction was to be expected for the EB tunnel drive, which passed beneath a significant number of the piers. This provided further evidence of the benefit of driving the WB tunnel first. As the viaduct is curved there were also concerns about tunnelling-induced horizontal as well as vertical displacements and so both were monitored using water levels and tilt meters respectively (judged to have sufficiently high resolution and accuracy)



and equally horizontal and vertical jacks were planned. After many discussions between all parties and iterations, a trigger system was decided upon based on the available capacity of the jacks.

Initial surveys of the flyover deck and piers showed that the central two piers had settled over the four-year period of its operation and so the spans either side of the central span already has some curvature (differential slopes). Detailed predictions were made of settlements during intermediate stages of the transit to assess critical locations of the TBM. This indicated that on completion of the transit the existing slope would reduce at the southern end, i.e., improving the situation, but that some jacking might be necessary at some of the intermediate stages. In view of this the philosophy adopted was to observe closely during the transit, knowing that slopes might improve and as well as worsen, and then to take action (after discussion) using the jacks. Therefore a passive approach was adopted rather than the original concept of controlling absolute levels to within tight tolerances.

The conclusion from all the analyses performed in advance of the works was to implement progressively the monitoring system to understand the background response of the structure (especially during the base-line period), adopt the strategy to construct the WB tunnel first and to allow some parts of the flyover to sag (improving conditions of existing slopes).

Above, left: ***Canning Town Station serves the Docklands Light Railway***

Above, right: ***Aerial view of Eastern London***

Below: ***Work ongoing on the Crossrail project***

MONITORING SYSTEMS AND MITIGATION MEASURES

Following detailed discussions and appraisals of the conditions on site, many modifications were made to the original desired scope of monitoring and control to provide systems that were achievable.

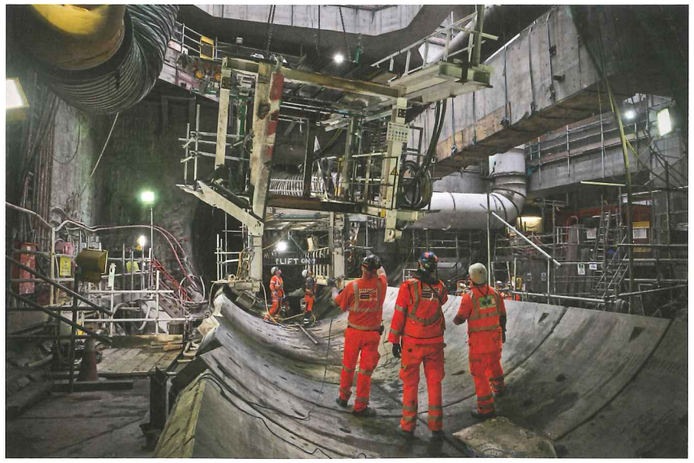
Very high tolerances of 0.3 mm were required from the monitoring systems, which precluded the use of traditional optical instruments such as automated total stations. Precise digital levels, with an accuracy of 0.3 mm, were therefore implemented with them daisy-chained from the north to the south of the flyover with a precise level set up midway that could sight to a deep datum, thus allowing absolute displacements to be determined along the whole structure.

Tilt sensors were installed on all the piers and so by basic geometry the absolute level of all the bearing locations could be accurately determined. Displacement transducers were also installed to monitor the distance between the top of the piers and the deck, which would allow the movements of the jacks to be monitored during the corrective jacking operations. Once the positions of the key parts of the structure were known the virtual reference line was set up, to which all relative movements were to be controlled within a set tolerance.

As the monitoring system was so key to the successful protection of the flyover structure, assurances had to be provided that it would be as reliable and fail safe as practicably possible. The cabling to all the instruments was assessed like an electrical circuit so that if any part was cut the instruments would not be affected.

Therefore back-up power supplies were provided along with redundancy in the control systems so that none of the instruments would lose power or data.

In designing the hydraulic systems for jacking careful



appraisal of the flyover structure was made, assessing factors like its articulation and the forces transmitted through the bearings. Bespoke pumps were then designed to provide the necessary capacity and control, in both horizontal and vertical senses and during both individual bearing replacement and tunnelling activities. Prior to installing the jacks and after testing all the individual components, a full-scale trial modelling one of the piers was set up and the hydraulic system tested by imposing displacements and twists similar to those anticipated during tunnelling. Even factors such as realistic hose lengths of 150m were implemented (as this can affect response time). This exercise gave invaluable experience and provided confidence in the planned system.

Once installed, the vertical jacks essentially became temporary bearings (the original bearings were removed), thus supporting the structure, and they had to sustain this role for an 18-month period – an unusual requirement. In designing the jacks, in addition to the vertical forces they had to carry, consideration also had to be given to the fact that they should be able to operate when the deck is translating laterally or rotating. Locking collars were provided as a safety precaution, so that only a fixed displacement (of about 1mm) would take place if there were a malfunction of the hydraulic system. The horizontal jacks were essentially floating and were to hold the deck in position but to allow the piers to rotate.

FOREWARNED

As the Crossrail works were anticipated at the time the flyover was designed and constructed, anchors were cast into it to support the jacks. However, these were found to not be usable due to their location and form and so structural steelwork frames and clamping devices had to be designed and installed to apply the hydraulic systems.

Planning the installation of the various hydraulic and monitoring systems was very complex due to the small and very congested nature of the site, the need for DLR possessions for access, and additionally the time frame for the installation works was tight. As some parts of the site were inaccessible most of the time, a temporary bridge was constructed to access a central island area so that work could run 24 hours a day. This was also useful for maintenance and calibration of the instrumentation. At other locations, some of the works were so close to the existing tracks that the extent of the kinematic envelope of the trains had to be considered.

Lifting and installing the jacks were major operations, as they each weighed 0.5t. In some cases comprehensive steelwork systems had to be constructed just to install the jacks.

The entire operation had to be very carefully planned and precautions and back-up strategies were implemented at all stages to minimise risk to the flyover and DLR operations. In total there were more than a thousand sensors with vast quantities of raw and processed data that had to be managed.

As well as the trigger levels linked to the structural tolerances, additional functionality and integrity alert systems were set up to ensure that the instrumentation was working properly. Templates were developed to allow the vast data sets to be presented in a meaningful way so that the various parties could assess them quickly and make decisions and take necessary actions.

OBSERVED RESPONSES

The jacks were installed 18 months in advance of the tunnelling and the early setting up of the monitoring allowed background, and in particular thermal responses, to be identified.

A linear thermal response of the flyover to temperature change was observed with expansion and contraction with respective warming and cooling. Reassuringly the fixed point was very close to the point where zero change occurred.

With the flyover supported on the jacks, the instrumentation was sensitive enough to register when the DLR trains passed over.

As the layout of the piers was not uniform, the forces on the various jacks acted in multiple directions. It was very important to understand this behaviour in advance of the tunnelling when it would be necessary to control the jacks.

Installation of the fixed bearing at this point was very difficult and once in position the temporary structural steelwork and jacks were subjected to enormous forces from the structure. The flyover at this location did move longitudinally, initially it was thought that the capacity of the jacks would not be able to match the magnitude of the forces, but with the jacking loads applied in incremental steps, it was possible to induce small displacements and to control the movements.

In the case of the movement joint SA0, horizontal and vertical jacks were installed to take over its function during the tunnelling works – without horizontal control there could have been problems with the railway and the vertical control helped maintain lateral tilt of the transition slab within tolerance. Initially there was much noise with data spikes extending into the red trigger level zone.

It was important to have better conditioned data prior to the first tunnel drive and this was achieved by installing voltage regulators and modifying the method of processing the data. There was a clear change evident in the graph, in time for the tunnel drive, allowing careful control of the jacks.

During the tunnelling works, the monitoring data were continuously assessed and reasons for irregularities checked immediately. Frequent meetings were held to ensure that the data were interrogated properly and tolerances maintained.

Excellent control of tunnelling volume losses were achieved for the WB tunnel (<0.2 per cent), which allowed the whole system to be checked without operating it to its full capacity. Larger movements occurred during the EB drive (volume loss still only about 0.4 per cent) but the viaduct was successfully controlled by carefully staged control of the jacks using feedback from the monitoring systems.

Questions from the floor

Gary Brierley, Doctor Mole Inc., USA: How did you distribute the predicted settlement troughs across the deep piled foundations?

Answer: It was assumed that the solid pier would behave monolithically [en masse] and the piles be tied together by it. The settlement at two-thirds of the pile group depth were taken on the left- and right-hand sides and the assumption made that the pier would move as a linear element in conformance with that. It seemed a reasonable approximation given all the other factors to be taken into account.

Barry New, Geotechnical Consulting Group. I have two questions: (i) How much did the jacking system cost; (ii) what would have happened given the ground loss performance, if you hadn't done anything at all?

Answer: The scheme cost several million GBP. The structure came to the limit of the amber threshold on the basis of the 0.2 and 0.4 per cent volume loss. In hindsight it might have been just about acceptable but decisions had to be made six months before the TBMs went through and Crossrail had to give DLR a guarantee that their trains would be able to continue running safely. The 1 per cent volume loss was the worst credible at that time and this was the value that we worked to. Things could have been much worse if the tunnelling had not been in London Clay and it would not have been very risky to have an assumed a 0.3 per cent volume loss at that time.

Neville Harrison, retired: The values set as trigger levels were less than 10 mm – these seem low in view of the fact that weather and temperature can have a strong influence on a structure's movements. He recalled an example where Grey's Monument in Newcastle was being monitored and was found to move by about 25 mm due to sun.

Answer: This is definitely true, for example during the Jubilee Line Extension works the Big Ben clock tower at Westminster was found to move diurnally as a result of tidal and solar effects. At Canning Town the flyover could expand and contract by up to about 35mm longitudinally. The curved alignment of the flyover meant that the longitudinal movements also caused it to bow by about 5mm, which was exacerbated by the sun shining on alternate sides of it during the course of the day. Changes in the ground water table were evident from tidal effects but these did not seem to affect the bridge. A further intriguing response was caused by the fact that as the steel central section of the flyover reacted more quickly than the concrete side spans a spiralling pattern was observed. These movements were all greater than those anticipated from the TBM, it was important to understand them in advance so as to be able to isolate them.

Vinno Balakumarasingham, Waterman Group. Two questions: (i) with so many variables was your engineering judgement challenged at times? (ii) Is there any counter-intuitive that you will carry forward to future similar projects?

Answer: At the daily review meetings the data from the instrumentation invariably looked erroneous and were checked and found to be correct – sometimes the behaviour of the structure was counter-intuitive – this was particularly so during the base-line monitoring and highlights the importance of this period to help understand the background responses so that during the transit – when occasionally there were unclear responses – at least the non-tunnelling associated movements were reasonably well understood. A particular point worth mentioning, re counter-intuitive responses, concerns the CPN fixed point where longitudinal jacks were located. These were not capable of shifting the 7,000t deck but in conjunction with the longitudinal thermal movements it was possible to control the deck movements northwards: it was surprising in this case that the theory worked out in practice.

Roger Bridge, Balfour Beatty (BTS chairman): The flyover was designed with mitigation measures to take into account the tunnelling that was due to take place some years later (i.e. the designers knew that the flyover would be influenced by future Crossrail construction). How well did that work? Are there lessons that can be taken forward with this regard?

Answer: It would have been good if the structure were more tolerant to displacements. The fact that the deck was continuous from end to end made safeguarding it difficult. If there had been individual spans with greater articulation it would have been a simpler structure to work with but then it would not have met the objectives of the original structure – the only way of achieving it would have been to have a continuous S-shaped span.

Rapporteur: Jamie Standing, Imperial College London

PRIMARY CONCLUSIONS

The importance of team work and interaction with all parties involved was emphasised. The relationships developed among individuals from all parties resulted in what could have been major issues being resolved smoothly, even under pressure. The main lessons from this project can be summarised as follows.

1. It was essential to set up a workable approvals structure with all the various parties on board and an interface control plan in place.
2. The primary mitigation measure was to control face loss (this was assisted greatly by adopting EPBMs).
3. Assessment of overall risk meant identifying the unmanageable risks and controlling those with which could be dealt. Installing the comprehensive monitoring and jacking systems allowed much better control of risk.
4. Having more instruments means more data (the need to condition and interpret them) and potentially more false alarms.
5. Simple checks are essential (and development of check sheets, flow charts, etc.).
6. Experience was gained in steps, gradually making progress, increasing knowledge (e.g., base line readings, dewatering operations and the experience from the WB drive).
7. Adopt a passive approach where possible (i.e., not reacting too hastily without carefully thinking through consequences, assessing whether conditions might settle down, and pre-emptive jacking in anticipation of tunnelling-induced ground movements).
8. Importance of teamwork, enabling issues to be resolved quickly and smoothly, even under pressure

The presenters were contacted for the diagrams presented at the BTS meeting but were unable to send them before Tunnels and Tunnelling went to press. Readers can access the full presentation on the BTS website

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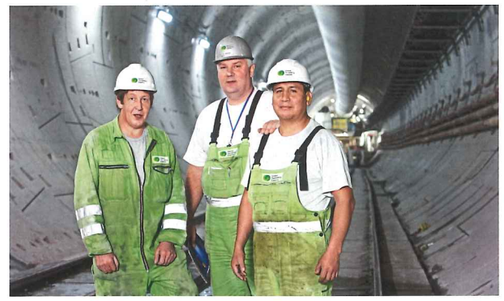

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What's on

2016

International Symposium on Tunnel Safety and Security
16-18 March 2016
Montreal, Canada
Tunnel safety and security is a challenge for both private and public sectors. ISTSS provides a forum to discuss current practice and emerging trends and research in safety and security.
www.istss.se/en

China Tunnel and Bridge Summit
17-18 March 2016
Zhuhai, China
With the 12th five-year plan, China accelerated infrastructure construction and achieved a leap forward in development. Lots of sea- and river-crossing projects sprung up.
www.merisis-asia.com

NASTT's No Dig Show
20-24 March 2016
Dallas, USA
The overall No-Dig Show program is focused on one objective: helping you maximise your investment in trenchless technologies, services and applications. If you sell trenchless products and services you'll want to be sure to exhibit.
www.nodigshow.com

Bauma Munich
11-17 April 2016
Munich, Germany
The 31st meeting of the world's largest trade fair for construction machinery, building material machines, mining machines, construction vehicles and construction equipment returns to its traditional home: the Neue Messe Munchen exhibition centre in eastern Munich. Bauma is a global driving force behind innovations.
www.bauma.de/en

Infrarail
12-14 April 2016
London, UK
The UK's definitive railway infrastrcture exhibit. Infrarail 2016 takes place against a background of high levels of investment in Britain's main line and urban rail infrastructure. Network Rail has embarked on its GBP 38 billion CP5 spending round.
www.infrarail.com

International Symposium on Submerged Floating Tunnels and Underwater Structures
20-22 April 2016
Chongqing, China
This event, organised by the National Engineering Laboratory for Highway Tunnel Construction Technology, the China Institute of Mechanics, the Chinese Academy of Sciences, and the University of Naples will cover all topics from conceptual design up to operational emergency rescue.
www.cmct.cn

World Tunnel Congress and NAT
22-28 April 2016
San Francisco, California
The 2016 World Tunnel Congress (WTC) and the 39th General Assembly of the International Tunnelling and Underground Space Association (ITA) will be held in conjunction with the UCA's North American Tunnelling conference.
www.wtc2016.us

Underground Construction Prague and EETC
23-25 May 2016
Prague, Czech Republic
Delegates are cordially invited to the thirteenth Underground Construction (UC) Prague Conference.
www.ucprague.com

Swiss Tunnel Congress 2016
15-17 June 2016
Lucerne, Switzerland
The annual Swiss Tunnel Congress (STS) is organised by the Swiss Tunnelling Society and is the premier event for tunnelling in Switzerland. Approximately 800 delegates attend from around 15 nations to take in the high quality presentations.
www.swisstunnel.ch/en

Urban Underground Space & Tunneling Asia Summit
6-9 September 2016
Singapore
Asia's Leading Urban Underground Space & Tunneling Summit will return to discuss leading practices, innovative techniques and sustainable solutions for Design, Engineering & Construction of Underground Space and Tunneling Projects. Learn best practice techniques and strategies from global experts.
www.equip-global.com

No Dig Live UK
20-22 September 2016
Peterborough, UK
Following the success of No Dig Live UK held in September 2014, the 13th biennial trenchless technology exhibition, outdoor demonstrations and seminars will return to Peterborough. Visitors to thie show were offered a wide ranging programme of educational opportunities.
www.nodiglive.co.uk

Innotrans
20-23 September 2016
Berlin, Germany
InnoTrans is the leading international trade fair for transportation technology, and takes places every two years in Berlin, Germany. The event is sub-divided into the five segments Railway Technology, Railway Infrastructure, Public Transport, Interiors and Tunnel Construction.
www.innotrans.com

BTS Conference and Exhibition
11-12 October 2016
London, UK
The British Tunnelling Society is pleased to announce the highlight of its 2016 events calendar, held at the QE2 Conference Centre in Westminster. Presentation synopses of 250 words are now being accepted for consideration with a deadline of 26 February. For more details please visit the society website.
www.britishtunnelling.org.uk

Expo Tunnel
19-21 October 2016
Bologna, Italy
ExpoTunnel is an exhibition dedicated to the world of tunnelling, drilling, mining, underground construction and research. It is an opportunity to meet in a global framework of supply and demand of high technology and its field applications, with the chance to learn new methods and harness new techniques.
www.expotunnel.it

Bauma China
22-25 November 2016
Shanghai, China
Bauma China is Asia's largest and most important event for the construction industry. It attracts international buyers—a fact that guarantees a high return on your investment as well as sustainable success. The show is a platform for product presentations and a grand industry party for communication.
www.bauma-china.com

TBM DiGs
16-18 November 2016
Istanbul, Turkey
Turkey has a great potential of Tunnelling and in the near future the country is expecting to see upwards of USD 35bn of investment in underground construction.
www.tbmdigsturkey.org

Bauma Conexpo India
12-15 December 2016
Delhi, India
The International Trade Fair for Construction Machinery, Building Material Machines, Mining Machines and Construction Vehicles—provides the construction industry in India with a professional platform for networking, investment and the exchange of ideas and information. The show launched in 2011 and did an impressive job of putting this quality standard to the test.
www.bc-india.com

2017

World Tunnel Congress
9-16 June 2017
Bergen, Norway
The theme of the 2017 WTC is 'surface problems - underground solutions'. The Norwegian tunnelling industry produces tens of kilometres of drill and blast tunnel every year and is keen to share its expertise with attendees.
www.wtc2017.no

GeoMEast2017
15-19 July 2017
Sharm El-Sheik, Egypt
Recent rapid construction in Egypt has provided great opportunities for tunnel engineers to use their knowledge and talents to solve many challenging problems with innovative solutions and cutting-edge technologies. GeoMEast 2017 will provide a showcase for recent developments.
www.geomeast2017.org

2018

World Tunnel Congress
20-26 April 2018
Dubai, UAE
The World Tunnel Congress heads to the United Arab Emirastes in 2018, and demonstrates the rise of the Middle East to the centre stage of the global tunnelling market.
www.uaesocietyofengineers.com

The British Tunnelling Society

The BTS has a membership of over 814 individual and 266 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Regular BTS monthly meetings are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month. In recent years, the BTS Young Members (BTSYM) group has also begun hosting its own events.

Mission Control: monitoring temporary works in tunnels
17 March 2016
The presentation will describe the application of 'cloud based data' to real time review of temporary works performance against design within tunnels, illustrated by a number of example projects in the UK and Hong Kong.
Speaker: Angus Maxwell of Maxwell Geosystems, Anmol Bedi of BAM Nutall

Harding Prize Presentations
21 April 2016
The annual competition is named in honour of Sir Harold Harding, founder chairman of the BTS and is open to engineers aged 33 or under. Entrants must submit an original paper relating to any aspect of tunnelling which they consider of interest to the industry. The winning paper is selected by members of the BTS Committee. Further details can be found on the society website. The winner receives two tickets to the BTS Annual Dinner, a copy of Sir Harold's book 'Tunnelling History and My Own Involvement', and a cheque for GBP 500.
Speakers: Harding Prize finalists

BTS Annual Dinner
6 May 2016
The BTS holds an Annual Dinner each year in May. The 28th Annual Dinner will be held at the Brewery on Friday 6 May 2016. Further details will be available shortly before booking opens in early February. Last year's event drew 848 attendees, the largest number since the BTS began keeping records in 1996.
Tickets for this event will become available from the BTS website

AGM followed by presentation on Singapore's Thomson Line
19 May 2016
Singapore's 30km all-underground Thomson Line (TSL) involves the operation of 30 TBMs to complete the twin running tunnels and the construction of 22 underground stations including 6 interchange stations. This involves a number of challenges in complex urban areas and partially reclaimed land.
Speakers: Andreas Raedle, Leo Suhaendi and Rob Harding of Arup, and a yet to be confirmed representative of the LTA

Harding Memorial Lecture
16 June 2016
The Harding Lecture is named after the founder Chairman of the Society, Sir Harold Harding and is given every second year. The lecture is given by an eminent speaker who presents a lecture on their specialist, tunnelling related subject.
The speaker has yet to be confirmed

The Emscher Interceptor
22 September 2016
A presentation on the construction of the Emscher wastewater tunnel which runs 35km from Dortmund to Bottrop. Pipe jacking ranged from 1.6 to 2.8m internal diameter with interlinking conduit sections in excess of 1,100m in length.
Klaus Rieker, Wayss & Freytag

If you have a topic or project you feel would be suitable for a BTS evening presentation, please contact:

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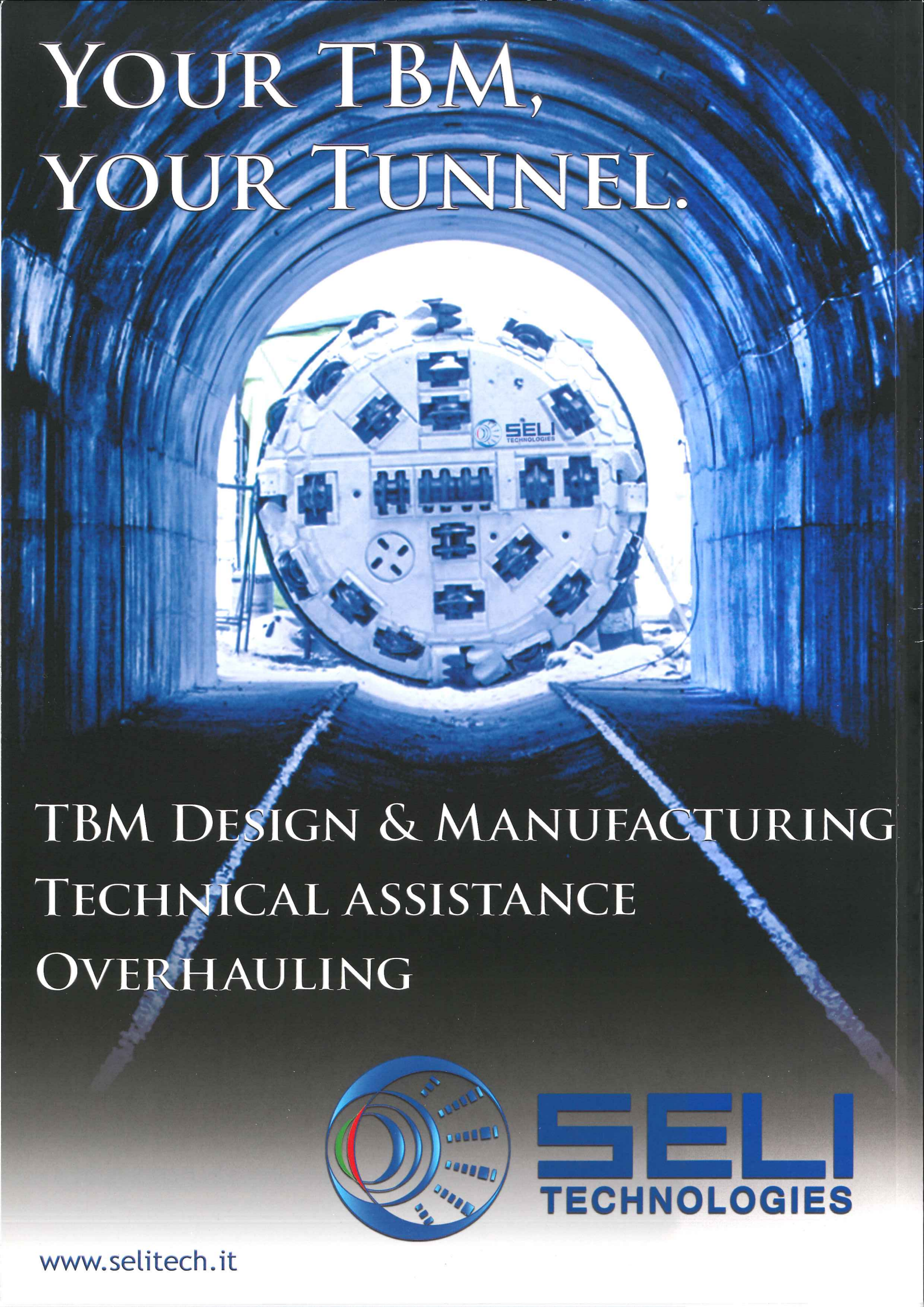

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