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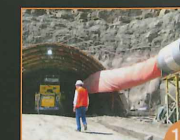
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DECEMBER 2011

tunnels & tunnelling

INTERNATIONAL



Latin America

T&TI investigates the demand-led tunnelling boom that has hit Latin America,

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The latest developments and advances in the fast-moving field of jacking

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Annum aghast

As I write, Egypt is on the verge of its first free elections in over half a century. Numerous Arab leaders have been ousted. The UK parliament is investigating a major media phone hacking scandal. The Euro is under threat of collapse. Greece, Italy and Spain are broke. Encampments remain in prominent financial districts round the globe. The world's seven billionth inhabitant is preparing for her first winter. Physicists are debating the accuracy of $E=MC^2$. And a 19.25m TBM is onsite and being readied to bore in Saint Petersburg.

It is traditional at this time of year to look at the past 12 months and draw some conclusions, some lessons learnt, mistakes made and some thoughts for the year ahead. But the chaotic year behind us leaves this editor aghast.

Twenty eleven has seen the world on its head. Politicians have turned the tables on media mogul Rupert Murdoch, calling him before a committee to face allegations of his newspapers' phone hacking. Arab states have overthrown their dictators and set off on the road to democracy while Western countries come under attack for eroding their citizens' liberties – the US has been dogged with cries of police brutality and the UK has faced calls to try terrorism suspects imprisoned for years without charges.

The trump card in this deck is the announcement from Cern (European Organisation for Nuclear Research) and an Italian physics lab that researchers claim to have recorded neutrinos travelling faster than the speed of light, completely destroying our understanding of physics.

In the face of such turbulent times it is hard to imagine any business thriving. Yet the tunnelling industry is in a comparative boom. A new world's largest TBM at 19.25m diameter has been erected, a leap of nearly 4m on the previous record. London's Crossrail TBMs have been built for a project that has spent 30 years on the drawing board. Excavation was completed on the world's longest and deepest transport tunnel, the Gotthard Base Tunnel. The US has backed high-speed rail with USD 53bn, China has put up USD 162bn for metro development and the UK Government has pledged support for High-Speed Two.

Understanding the events of the past year is hard enough; the year ahead is anyone's guess. While the world gets back to the status quo, have a great winter break and from all the T&T team, have a happy New Year!

Jon Young

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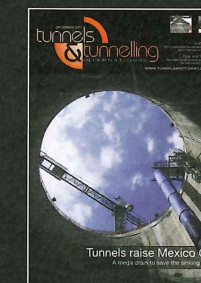
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T&T will be exploring projects in North America



On the cover:

The TEO project in Mexico City, Mexico supplements the deteriorating existing sewer system



In the supplement:

Forms used for the concrete lining operations at the South Cobb tunnel



ROSWITHA IS SPEEDING UP THE RAILWAY.

The Kaiser-Wilhelm-Tunnel near Cochem on the Moselle River which was built 130 years ago as Germany's longest tunnel must be modernized to meet higher safety requirements in the future. Therefore, the Deutsche Bahn railway company commissioned the new construction of a second parallel tunnel tube with a length of 4,242 meters. On November 7, 2011, the tunnel constructors and the population of Cochem celebrated the breakthrough of the Herrenknecht EPB Shield S-547 (Ø 10,110mm) nicknamed Roswitha.

During operation, the TBM excavated 900,000 tonnes of rock which was removed via a conveyor system of the Herrenknecht subsidiary H+E Logistik. The TUNIS system for the precise navigation of the machine weighing 1,700 tonnes from VMT also comes from the Herrenknecht Group.

The plan is to start single-track railway operation through both tunnels in 2015, following the modernization of the old Kaiser-Wilhelm Tunnel. An investment in the future of an efficient rail infrastructure.

COCHEM | GERMANY

PROJECT DATA

S-547, EPB Shield
Diameter: 10,110mm
Cutterhead power: 1,100kW
Tunnel length: 4,242m
Geology: argillaceous slate, sandstone, quartzite, siltstone and porphyry

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China launches monster metro plans

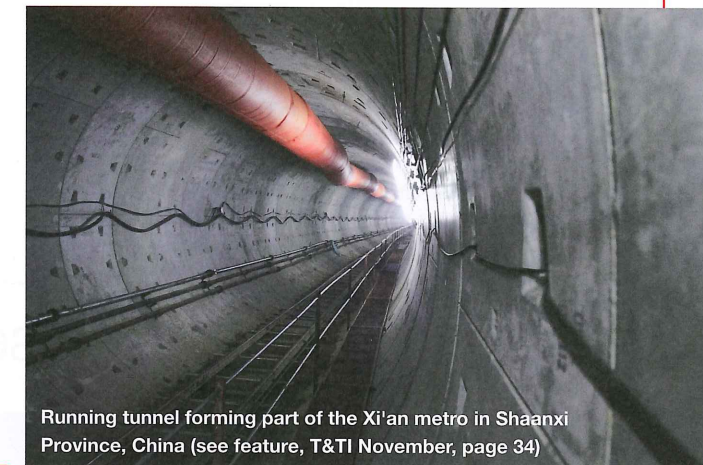
CHINA

China has pledged to invest over USD 161bn in metro projects for 28 cities. As of November, some 12 cities in the country had metro networks. The plan announced by the China Communications and Transport Association last month would see a total network 250 times the length of the London Underground Circle Line. Over 90 new lines were approved.

The focus was on metros for

smaller cities such as Taiyuan, Urumqi and Shijiazhuang. Other small cities including Dali, Haikou, Zhuzhou and Luoyang were preparing their own proposals as T&T went to press.

Zhao Jian told the press that all existing metros have failed to become profitable, though they have been seen as a symbol of progress for smaller cities and increased traffic will raise the need. Funding will likely come from bank loans as many local governments in China are heavily in debt.



Running tunnel forming part of the Xi'an metro in Shaanxi Province, China (see feature, T&T November, page 34)

News in brief

▼ **Swedish sealing system for longest immersed tunnel**
Swedish engineering group Trelleborg Infrastructure was last month chosen to supply a tunnel sealing system for the subsea Hong Kong-Zhuhai-Macau bridge-tunnel. China Communications Construction Company awarded the contract. The water depth will exceed 40m. The system comprises Gina gaskets, Omega seals and W9Ui inextensible waterstops.

▼ **Pike River Mine boss faces criminal charges**
Former Pike River Coal chief executive Peter Whittall is to face 12 criminal charges. The company will face 10 and drilling firm VLI faces three, all related to safety standards. The Pike River disaster in New Zealand last year killed 29 miners. Each charge carries a potential fine of USD 195,000.

▼ **Urheilupuisto Station tunnels contract awarded**
Finnish contractor Lemminkainen will construct a 160m driveway tunnel and 1.9km metro tunnel for Urheilupuisto Station. The USD 18.7M contract forms part of the West Metro route

US high-speed RFQs

USA

The California High-Speed Rail Authority (CHSRA) last month issued a request for qualifications (RFQ) from prospective design-build firms interested in building the largest construction package for the Central Valley.

This segment will begin north of the San Joaquin River near Madera and continue south to Fresno. It will run for 21 to 29 miles (34 to 47km) depending on the final alignment selected through the environmental process. The alignment will include 12 grade separations, two viaducts, one tunnel and a major river crossing over the San Joaquin River.

The 60-day RFQ process will establish a shortlist that will then be eligible to submit proposals for a request for proposal (RFP)

from Helsinki to Espoo in Finland. Construction will begin in January to be completed in late 2013.

▼ **Success through tunnel avoidance in Kosovo**
US-based Bechtel and Turkish engineering firm Enka announced last month that

process that CHSRA anticipates releasing in spring 2012. At the end of this procurement process, the selected design-build firm will be responsible for all work required to design and construct the first portion of the initial construction segment in the Central Valley.

Initial construction will begin late next year, upon completion of the environmental process. With an estimated value of USD 1.5bn to 2bn, this large design-build construction contract will be placed before the end of 2012. Smaller construction packages, focused in and around the City of Fresno, will be released for bid in the coming months and awarded in mid-2012.

The RFQ is posted online and is available from the authority's website. Visit: www.cahighspeedrail.ca.gov/construction.aspx

they had completed the first stretch of the 102km Kosovo motorway. A spokesman added, "The JV's optimum alignment solution enabled us to avoid the requirement to build nearly 5km of tunnel, resulting in significant cost savings for the government and the people of Kosovo."

US senate approves Amtrak funding

USA

The US Senate last month approved USD 15M for design and engineering work on Amtrak's proposed Gateway Tunnel, part of a rail project to link Secaucus, New Jersey, to Penn Station, New York.

Two new rails tunnels would be constructed under the Hudson River as part of the mammoth project.

Amtrak's CEO proposed the line in February following last year's cancellation of the ARC tunnel by New Jersey governor Chris Christie.

"This funding will allow Amtrak to begin moving the Gateway Tunnel project forward to create jobs, increase access to commuter trains, and bring America's first real high-speed rail project to New Jersey and the Northeast Corridor," said Sen. Frank Lautenberg, D-N.J. The bill will now go before a vote in the House.

Amtrak estimated the project could be completed by 2020 with a USD 13.5bn price tag.

Commons: good case for HS2

GREAT BRITAIN

The UK House of Commons Transport Committee announced last month that there was a good case for the High Speed Two (HS2) north-south rail link. The GBP 32bn (USD 51.4bn) project will connect London to

the West Midlands and then further north if plans go ahead.

"The UK is sometimes accused of failing to invest sufficiently in its transport infrastructure and of not planning for the long term," said the report. "Whether or not this is accurate, the Government is now proposing what is probably the

largest single investment in UK transport infrastructure in modern times—HS2. Unlike policies for major roads and airports, this proposal has all-party support. It is not, however, universally supported by Members of Parliament or the public."

The report added that the route

must be extended to Leeds and Manchester, as well as setting out a number of other conditions including full case assessments for the project to be carried out as a matter of urgency.

To read the report in full visit the UK Parliament's publications site: www.publications.parliament.uk

Second TBM starts on southern subway tunnels

USA

The second TBM to excavate Toronto's subway project from Sheppard West Station to Finch West Station was launched last month.

Part of the Toronto-York Spadina Subway Extension, the 6.12m diameter Lovat TBM, nicknamed Moley should bore up to 15m per day and arrive at the Finch Station in early 2012. The first TBM, nicknamed Holey launched in July was expected to complete the 2.4km drive to Finch Station later this year as T&T went to press.

Canadian contractor Aecon was awarded the contract for construction of the Sheppard West Subway Station and southern tunnels in November 2010.



Above: Moley follows sister TBM Holey to excavate Toronto's Spadina subway extension

Smart stamps issued in Kuala Lumpur

MALAYSIA

The Government of Malaysia released stamps bearing graphics of TBMs, tunnel cross sections and the breakthrough on the Stormwater Management and Road Tunnel (Smart) in Kuala Lumpur. Chris Davis, managing director of transportation for project designer and consultant Mott MacDonald said, "The commemorative stamps demonstrate how important the Smart is to the people of Kuala Lumpur. Since its opening in May 2007 SMART has been alleviating

traffic congestion and has been used to protect Kuala Lumpur from flooding at least 50 times.

"We are very proud of this project and we're delighted for it to be recognised in this very unique way."

The 13.2m-diameter Smart faced significant geological and technical risks. The spokesman said, "Intensive site investigation and ground improvement, meticulous attention to detail during specification of tunnel boring equipment, careful project management and close supervision ensured tunnel works

were completed without major incident. The tunnel was constructed in just two years and for a small budget of GBP 300M (USD 470M).

"Six of the tunnel's 9.8km are dedicated to flood relief, with the central 3km fulfilling the dual role. Traffic in this section is accommodated on two decks. Floods are able to flow through the bottom of the tunnel, beneath the lower road deck. Decks are protected from inundation by guillotine style gates. Road decks will be closed to traffic during extreme flood events."



Coming home for Christmas

WORLDWIDE

Sadly high 14.3 per cent of tunnellers will not be coming home for Christmas. The figure came from a poll issued by T&T last month. Fortunately, festivities were planned by all those T&T contacted when checking these findings.

Joseph Gallagher (JGL) contracts director Dickie Dexter told T&T that it tries to end work on 23 December where the main contractor allows, coming back on 3 January. He added, "Some are back on the 3rd however, though on one site we close up on the 16th so a two-week break there."

Contracts manager at JGL, Andrew Smith added, "Where we are in overall control we try to shut down for two weeks. As a significant part of our workforce is Irish, much of it returns home for the holiday. Costain's NG project, where we have a major involvement, is shutting down for the two weeks.

"There will be no lonely JGL tunnellers over Christmas."

Robbins' field service engineer, Elisa Comis returned to the US head office from India in October and said, "Everyone is already talking about the big Christmas party held in the workshop, it's never too early for Christmas. I'll stay for that and then fly home to Italy, where I haven't spent Christmas for three years."

Desiree Willis, Robbins technical writer, added, "The party this year is in our Solon, Ohio, USA manufacturing facility. Production shuts down during the event, so that Lok Home [president of Robbins] can give an annual presentation before the feast. We don't have a secret Santa - Lok is our Santa. Every year employees pre-select a range of gifts, including wines, steaks, and hams. These are presented at the end of the party. We also send out handwritten Robbins cards every year to our clients. And no, I can't tell you what I am buying Brianna

Home [Robbins marketing director], that's top secret."

From Japan, Risa Hirano of Hitachi Zosen said, "Christmas isn't a holiday here, but we do celebrate 'The Emperor's Birthday' on 23 December - a lot of people take three day weekends. Almost everyone takes a year-end and New Year holiday, this is very important for the Japanese. We go home or visit our parents to stay together and shut down the offices and factories.

"On the last work day we hold a 'Nokai' [literal translation: finish party]. We eat a large sushi meal and drink sake [Japanese rice wine] and other drinks. We will then send personal greetings cards. Companies used to do this but not any more. We also travel around to our Japanese customers when work begins to give New Year's greetings."

At T&T Towers the editorial team is mentally and spiritually preparing for a free bar, care of the publisher. Location unprintable.

Algiers metro opens after decades of delays

ALGERIA

Doors on the Algiers metro slid open to passengers for the first time last month. This followed Algerian president Abdelaziz Bouteflika inaugurating the metro at a 'festival atmosphere' ribbon cutting ceremony on 31 October.

Algiers Metro Line One, running from Hai el badr in the southeast to Tafourah Grande Poste in the centre, has been under construction for nearly 30 years, though work was halted for a ten-year civil war and economic crisis.

Client Entreprise Metro d'Alger (EMA), developed the 6.5km line. Early tunnel works were carried out

by local firms, with a EUR 380M (USD 524.7M) contract for civil works, fitting out and E&M works awarded in 2006 to a Siemens-CAF-Vinci JV. Total cost of the metro was USD 1.2bn.

This was the second rail system of its kind in Africa following the Cairo metro. A further 3.5km extension is also planned by EMA.

Traffic unleashed into Thu Thiem Tunnel

VIETNAM

The Thu Thiem Tunnel was due to open to traffic in late November as T&T went to press. The USD 189M Thu Thiem Tunnel is part of the 22km East West Highway and runs under Saigon River at a four per cent maximum grade. It connects Ho Chi Minh Districts One and Two. The local government and the Japan International Cooperation

youth walk' through the tunnel, led by Le Hoang Quan, chairman of the People's Committee of Ho Chi Minh City.

The USD 189M Thu Thiem Tunnel is part of the 22km East West Highway and runs under Saigon River at a four per cent maximum grade. It connects Ho Chi Minh Districts One and Two. The local government and the Japan International Cooperation

Agency funded the tunnel jointly. Early in the tunnel's construction moisture had to be dealt with in the first two sections of the tunnel, though Oriental Consultant Company confirmed the ingress did not constitute leakage.

The final feasibility report was submitted in 1997. Construction on the project was due to begin in 2003, but was delayed until 2004 by 'family relocation difficulties'.

News in brief

■ **Cross River Rail tops Queensland priority list**
The Cross River Rail project in Brisbane, Australia, last month had its status upgraded to 'ready to proceed'. As T&T went to press it topped the project priority list. Local government minister Paul Lucas said, "We're now confident this project ticks all the boxes that [statutory infrastructure development body] Infrastructure Australia needs it to. The Federal Government has already recognised the national significance of Cross River Rail by investing USD 20M in the planning and feasibility assessment stage."

■ **Chun Wo breaks ground on new HATS effluent tunnel**
Chun Wo Development Holdings last month began construction of an effluent tunnel and disinfection facilities for the Harbour Area Treatment Scheme (HATS) 2A. Construction of the 880m-long tunnel will take 42 months to complete and cost HKD 680M (USD 87.3M).

■ **Wireless service in Chinese rail tunnels**
The Guangshen section of the Guangzhou-Shenzhen-Hong Kong Express Rail Link in China will have in-tunnel wireless coverage. Radio Frequency Systems was chosen to provide and install the coverage, provided by its Radiaflex cable system.

■ **Kaiser Wilhelm tunnel completed by Alpine**
FCC-owned Austrian contractor Alpine Construction has finished work on the USD 107.8M Kaiser Wilhelm tunnel. The 4.2km, 9m-diameter new tube on the Koblenz-Perle railway in Germany runs parallel to the old tube. Eight connecting passages will be built.

Leighton declares tough 2011 following major tunnelling losses

AUSTRALIA

Leighton Holdings Group chairman Stephen Johns said that the 2011 financial year had held 'serious challenges' for Leighton. Johns was speaking at its 50th AGM last month.

The Brisbane Airport Link was a blow to the company. Along with the Victoria Desalination project, Johns described it as a complex issue that was financially unacceptable. In February Leighton estimated full-year profits of AUD 480M (USD 476M). By April the outlook had become a AUD 427M (USD 423.5M) loss. Law firm Maurice Blackburn commenced a class action lawsuit in September on behalf of investors over the company's alleged failure to disclose the problems it was facing on 'key infrastructure projects'.

Head of the Maurice Blackburn class actions department Andrew Watson said Leighton was in breach of the continuous disclosure provisions of the Corporations Act. The revised loss on the Brisbane Airport Link was AUD 470M (USD 466.1M). The Victoria Desalination Plant was described as on time and on schedule on five occasions between November 2010 and March 2011. Watson added, "It is difficult to understand how Leighton can justify these statements in light of its sudden announcement on 11 April 2011 that the project was suffering serious delays and costs overruns."

Leighton CEO Hamish Tyrwhitt was appointed suddenly in August within 24 hours of the departure of his predecessor David Stewart, who in turn replaced Wal King in

January. Tyrwhitt commented, "I am bringing more rigour and discipline to project selection and pricing. Our positive outlook and enhanced focus on risk management gives me confidence in our ability to return to creating real value for our shareholders."

Attempts to reach Leighton for comment went unanswered.

Despite the tribulations, the group's third quarter results showed an audited revenue increase of AUD 1.4bn (USD 1.42bn) on the 2010 results and a corresponding profit-after-tax increase of AUD 252.5M (USD 255.25M). The figures did not include gains on the sale of HWE Mining concluded on 30 September.

Johns said, "Leighton is a business that is extremely well placed and with a new CEO, who is supported by a capable and

experienced management team, the board looks forward to rewarding shareholders for their support in the years ahead."

Tyrwhitt added, "As well as our exposure to the resources sector, Australia offers us a substantial range of infrastructure opportunities, underpinned by a growing economy and an expanding population. Recent forecasts suggested that the total value of engineering and commercial construction will rise by over 10 per cent in 2011/12 and by 12 per cent in 2012/13 with engineering construction growing even faster."

"The Leighton Group's underlying strength is reflected in our work in hand which remains around AUD 45bn (USD 45.5bn). Over the next 2-3 months, we will be submitting tenders worth AUD 27bn (USD 27.3bn)."

Critchfield joins Parsons Brinckerhoff

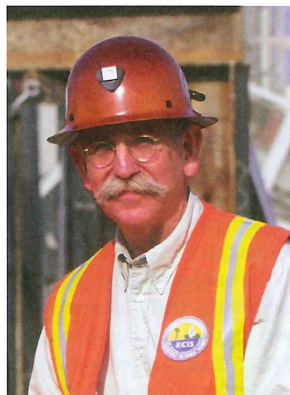
USA

John Critchfield joined Parsons Brinckerhoff (PB) last month. The new senior project engineer brought 36 years of geotechnical and underground engineering experience. Critchfield will manage construction, engineering and inspection of the underground work on the Port of Miami Tunnel. "In his new position, Critchfield will be responsible for managing construction engineering and inspection of underground works for the Port of Miami Tunnel project," a PB spokesman said last month. "Critchfield's experience has an emphasis on tunnelling."

Critchfield was educated at the University of Illinois-Urbana and

the University of Missouri Rolla. He is a member of the American Society of Civil Engineers and the American Underground Construction Association.

Below: John Critchfield



Mosen bags Else as engineering director

GREAT BRITAIN

Karl Else last month joined tunnel and fire safety specialist Mosen as engineering director. Else, an expert in computational fluid dynamics (CFD) and its application to the transport, mining and power sectors was head of building physics at HurleyPalmerFlatt (see feature, page 58).

Mosen managing director Fathi Tarada said, "Karl's appointment is a great milestone in Mosen's development as a leading consultancy in CFD, fire safety engineering and tunnel ventilation. His knowledge and experience will be highly regarded by our clients and benefit major projects."

A Mosen spokesman added, "After graduating from Brighton

Polytechnic in 1989 with a degree in mechanical engineering, Karl became a consultant specialising in CFD. Starting his professional career on the Channel Tunnel design team he developed his expertise in smoke control, industrial ventilation and condenser optimisation.

"During this time he worked with a wide range of clients in North and South America, Europe and Asia on site and as part of the design teams on the Delhi, Ankara and Copenhagen metro systems and the Attiko Metro in Athens.

"He worked in New York on the Hoboken, 33rd Street and World Trade Center stations. Then returned to work in the UK on the Heathrow Terminal Five station and the Thameslink and Crossrail stations at Farringdon."

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BORING THROUGH FUTURE

Tideway tribalism

The Thames Tunnel Commission (TTC)'s report on alternatives to the Thames Tideway

Project's Thames Tunnel only continued the impasse with Thames Water. TTC chair Lord Selborne said, "Our forensic analysis shows there is a substantial body of evidence pointing to the fact that there is a smarter way to make the River Thames cleaner. A shorter tunnel, combined with green infrastructure solutions that are built up incrementally in the medium to long term would be both compliant with EU directives and less costly and disruptive to Londoners. These alternatives require further study."

A Thames Water spokesman responded to the report two days later, "The report by Lord Selborne's TTC fails to provide a viable, economic or timely alternative to tackle the 39Mt of untreated sewage that overflows into the River Thames from London's Victorian sewers."

Phil Stride, head of the Thames Tunnel project at Thames Water said, "Nothing in the report begins to suggest a workable alternative to the Thames Tunnel, capable of meeting the objectives for the health of the river, set by the Environment Agency, in the timescale required by the Government. There is no mention of the need to achieve a timely solution, either to resolve an entirely unsatisfactory situation as soon as possible, or comply with an EU directive that has applied to member states since 2000."

"When London and the river need a decisive, long-term solution, the Selborne Commission is advocating a very short-sighted approach. For example, the shorter tunnel recommended in their report would leave 19 of London's 34 most-polluting sewage overflow points entirely untouched, and lead to significant



odour problems in west London."

Stride continued, "Sustainable urban drainage systems (Suds) feature heavily in the report. We agree they have an important role to play. The trouble is that meeting the Commission's calculation of even a 54 per cent reduction in sewer overflows through Suds measures would require disconnecting an area equivalent to 15,000 football pitches from the sewerage system. That's the equivalent of 40 Hyde Parks. This surely demonstrates that this would not be a simple, inexpensive or low impact option."

"The report also has nothing to say on how to tackle the sewage discharges in the more built-up areas downstream of Vauxhall Bridge, other than building a number of additional sewage treatment works in a highly urbanised area."

The second 14-week phase of consultation began on 4 November. Thames Water highlighted updated proposals of reduced greenfield use, some 90 per cent of spoil to be removed by

Above: Stephen Greenhalgh, Hammersmith and Fulham Councillor (left) with Lord Selborne, chairman of the Thames Tunnel Commission

barge or rail and that the project will create 4,000 jobs. As T&T went to press, Thames Water representatives were attending numerous 'save our park/church/riverside' meetings set up by local lobbyists.

The proposed Thames Tunnel 'super sewer' alignment runs from Acton in west London to Abbey Mills in the east. It was expected to cost GBP 3.6bn (USD 5.6bn) in 2008. Much of the opposition to the tunnel stemmed from the cost and a belief that it will rise. Lord Selborne said, "Many bill-payers will be pushed into water poverty which is not acceptable when there are viable alternatives."

The TTC was set up on 4 July by four London riverside boroughs: Hammersmith and Fulham (H&F), Kensington and Chelsea, Richmond, and also Southwark. This group levelled another accusation, this time at the Australian bank, Macquarie that bought Thames Water for GBP

8bn (USD 15bn) in 2006. The Thames Tunnel will see the regulatory capital value of Thames Water rise by over 40 per cent. A H&F spokesman added that this would enable large profits to be made on borrowings.

H&F Councillor Stephen Greenhalgh said, "Thames Water has a vested interest in pushing through this gold-plated scheme and this is why it has chosen to ignore the water industry experts who have repeatedly come forward to say there are alternatives. We now know that there is another way to improve the cleanliness of the river without the huge environmental, social and economic costs."

"Given the huge body of evidence now available against the super sewer it is time for Defra, backed by Ofwat and the Environment Agency, to compel Thames Water to go back to the drawing board."

Alex Conacher

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New world's largest for northern Russia

Plans were recently announced to utilise the world's largest diameter TBM to bore a highway tunnel under the River Neva in St Petersburg, Russia, to alleviate seasonal road and river traffic problems. Mikhail Ryzhevskiy of the project concessionaire, LLC Nevskaya Concession Company, explains the background and plans for the project soon to commence

This article tackles the peculiarities of a unique construction project, taking place in the 'northern capital' of the Russian Federation, Saint Petersburg. Saint Petersburg is located in on the delta of the River Neva near by the Gulf of Finland, part of the Baltic Sea. It has well developed rail and road networks, an air communication system, access to the Volga-Baltic Waterway (VBW) and also access to various gas and oil pipelines.

In 2005 the city government made a decision to start construction of a road tunnel under the River Neva. The project was needed to tackle:

1. Traffic jams;
2. Absence of continuous communication between the left and right banks of Saint-Petersburg;
3. Shortage of ship navigation time.

To realise this idea a project concession agreement was created. Under the terms of the concession agreement the following project participants were brought together:

- The government of Saint Petersburg (responsible performer of the project);
- A private investor (concessionaire);
- Ministry of Regional Development of the Russian Federation (Chief controller of the federal budget);
- The State management company.

In April 2010 the concession owner selected LLC 'Nevskaya Concession Company' (NCC) as the private partner for the project, and is in charge of

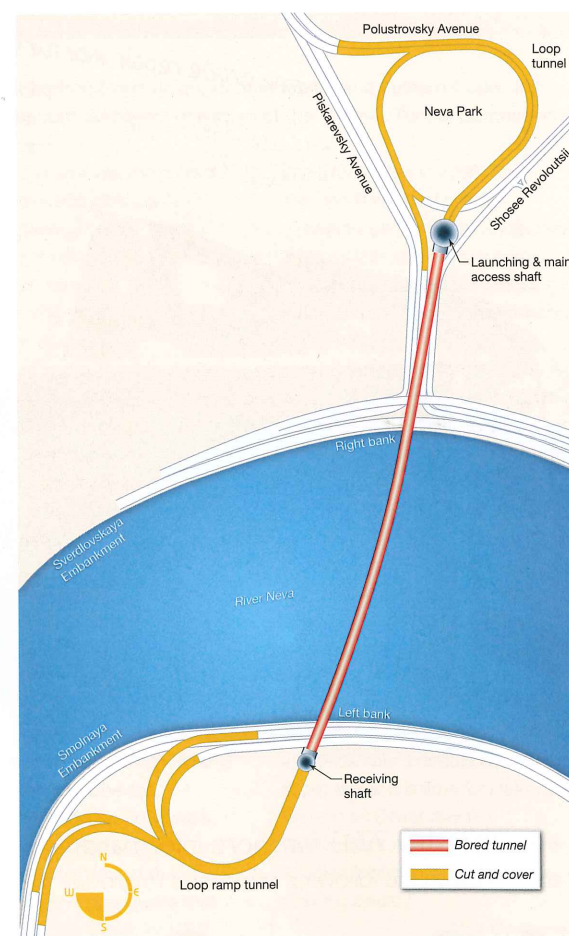
implementing the whole project. NCC engaged Stroyproject of Saint Petersburg as the main designer for performing tunnel design work. All directions concerning Orlovsky tunnel design come from NCC, and further checking of executed works are made by specialists from NCC. In addition, subcontractors were enlisted to carry out work on certain sections.

Tunnel description

Several options were examined while developing the concept of Orlovsky tunnel construction:

- Submersed tunnel: This is a relatively cheap solution. Implementation of this variant would require shipping restrictions on the River Neva, relocation of a municipal water intake, reconstruction of embankments, and with carrying over of utility systems. This method might incur high natural environment damage.
- Open cut method: This presupposes enclosure of the construction area with a restriction or with full closure of navigation on the River Neva. Realisation of this variant

requires carrying over of utility facilities from Smolnaya and Sverdlovskaya banks, reconstruction of embankments, and entails high ecological risks. An inexpensive option.



- EPB or slurry TBM: This technology allows to tunnelling in complicated geological conditions without damaging hydrogeological processes under the River Neva. The current methods do not hurt the ecosystem of the construction area. Usage of a TBM is a more expensive solution compared with the first two variants.

After comparison and risk analysis it was decided that the TBM method is more appropriate from technological and safety points of view.

After this choice several design scenarios for the TBM method were reviewed.

First scenario: The tunnel has a twin-bore configuration, with an excavation diameter of 15.2m for each bore, designed for three lanes of traffic in each direction;

Second scenario: The tunnel had a single bore, approximately 15.9 to 16.1m in excavation diameter, configured internally to accommodate two lanes of traffic in each direction on two levels;

Third scenario: A single-bore tunnel with a unique external TBM shield with a diameter of 19.27m and capacity to accommodate three lanes of traffic in each direction on two levels.

After thorough examination of the options it was decided to implement scenario three, which corresponds to European standards. Moreover, the third variant is technically and economically the most feasible.

The planned depth of the tunnel is going to be from 20 to 33m, and the length of the tunnel under the River Neva will be 956m but the traversed length of the Orlovsky tunnel is planned at about 3km.

The Orlovsky Tunnel complex includes

- Left: Figure 1, Plan of Orlovsky Tunnel alignment and connecting road routes;
- Right: Figure 2, Geological profile along tunnel route

the following main structures:

- Bored tunnel, located under River Neva;
- Road interchange at the right bank, which includes loop-shaped ramps with exits to Piskarevsky Avenue, Shosse Revoloutsii and Sverdlovskaya Embankment;
- Traffic interchange at the left bank, which encloses loop-shaped ramps for switching between the Orlovsky Tunnel to the Smolnaya Embankment;
- Operational facilities.

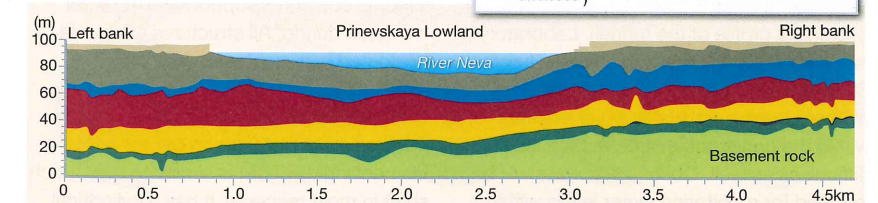
Interchange design

The Orlovsky Tunnel is going to be constructed between the Liteyny and Bolsheokhtinsky bridges. To connect the tunnel to street and road network it is planned to set up road interchanges at both riverbanks.

The main factors that define the road interchanges are:

- Given design limits, approved by the Committee for Urban Development and Architecture,
- Capacity for a design speed of 80km/h at the main tunnel alignment and 50km/h on access roads,
- Provision of minimal longitudinal inclination,
- Implementation of a transport layout that will be convenient and provide road safety.

A traffic interchange will access to the roads: Piskarevsky Avenue, Shosse Revoloutsii and Smolnaya Embankment and also two slip-roads from Sverdlovskaya



Embankment and Piskarevsky Avenue. The alignment of access roads to the tunnel itself will be realised via loop-shaped ramps on both riverbanks.

On the left riverbank the Orlovsky Tunnel will be connected to Smolnaya Embankment, which acts as a cross-distribution route.

The tunnel's connection to the historical centre of Saint Petersburg will be done through loop-shaped ramps.

The design for roadways on the right bank was developed within the assigned territory bounded by Piskarevsky Avenue, Shosse Revoloutsii and Polustrovsky Avenue.

Due to the depth of the tunnel alignment under the River Neva some sections of the tunnel on the right bank construction site will be built by a top-down/slurry wall method and open-cut method located in the 'Neva garden' area. This solution has been accepted to make shorter sections for further transition of the higher part of the tunnel to the street and road network. Taking this into consideration, a shallow subway from the end of the bored tunnel zone will be built consisting of two-level, loop-shaped ramps.

The number of carriageways on the ramps is identified by the rated traffic intensity in accordance with a traffic flow of 1,100 vehicles per hour.

Figure 1 (left) shows the roadway scheme and the tunnel alignment.

Geology

The city area includes a land mass area, numerous islands and peninsulas that are linked with each other by means of bridges and subway lines. There are about 100 rivers, streams, water-flows and approximately 20 canals within Saint-Petersburg. So there is a lot of water above and below St Peterburg as geological

surveys have proved. There is a presence of several aquifers within the zone of the Orlovsky Tunnel construction.

Saint Petersburg is temperate and humid with average annual temperature 4.3°C.

From a geomorphological point of view the construction area belongs to Litorinovaya Terrace of the Prinevskaya Lowland. The hydrographical network of the region refers to the Baltic Sea basin.

Geological investigations for the tunnel construction were held from August 2010 to December 2010.

The geology of Saint-Petersburg is presented by the following stratigraphy:

- Quaternary deposits;
- Sedimentary cover of rock basement (upper Vendian age - Proterozoic);
- Proterozoic basement.

The Quaternary sediments within a drilling depth of 101m are composed mainly of anthropogenic sediments of Holocene age (t IV), lacustrine and marine deposits (m, I IV), lacustrine-glacial (lg III), glacial deposits of the Luzhskaya glaciation phase (g III), intermoraine lacustrine-glacial deposits of the Moskovskiy horizon (lg II ms), and glacial sediments of the Moskovskaya glaciation phase (g II).

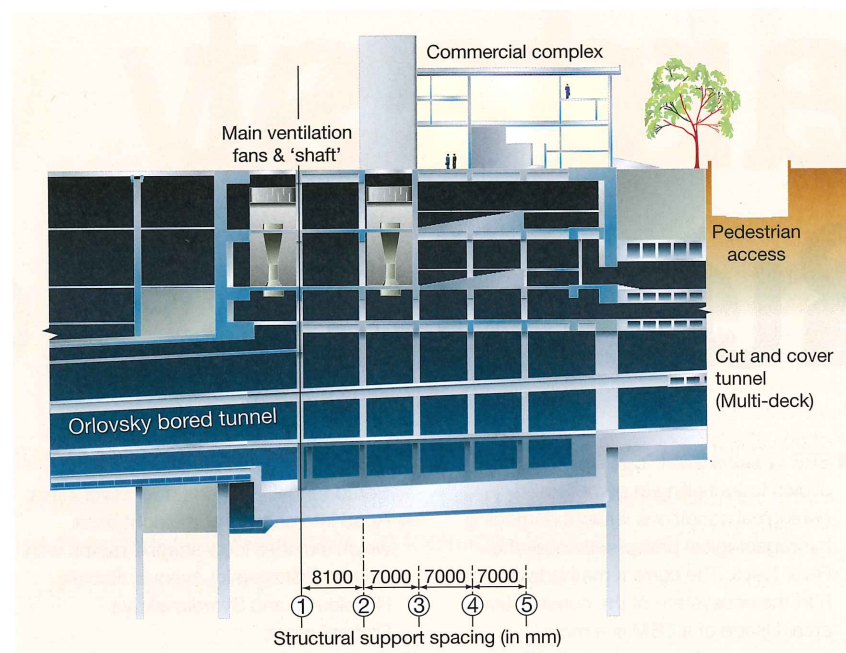
The sedimentary cover of the late Proterozoic age is composed mainly of claystone shales and are divided into the Kotlinsky level (Vk2) and the Gdovsky level. The upper part of the Kotlinsky level, that lies below the Quaternary sediments, is generally flat and is usually associated with constant thickness and lateral lithological uniformity.

The deep Proterozoic basement is mainly composed of biotite gneisses as a metamorphic basement.

The Orlovsky Tunnel is planned to be constructed in Quaternary sediments but the shafts will touch the Kotlinsky horizon.

Quaternary sediments are represented by sandy loam, sand, loamy sand, silt loam and silty clay loam (according to USDA classification). Based on field and laboratory results, specialists from NCC found out that most of the soils that will be involved in the Orlovsky Tunnel construction are soft, very soft, unconsolidated and water saturated. Moreover, some soils have thixotropic behaviour (Figure 2, page 13, shows the geological profile of the tunnel). Laboratory research was performed according Russian State Standards and British Standards.

There are several water driver aquifers within the construction area that cause difficulties as well. Observation wells will be installed for monitoring water levels within



construction site.

All these peculiarities and complicated geological structure are considered in design solutions for Orlovsky tunnel

The tunnel can be divided into three parts: launch and dismantling shafts and the tunnel itself under groundwater.

Right bank shaft

All the accepted design concepts are based on checked geomechanical and static calculations. The TBM launch shaft on the right bank has cylindrical form with a diameter of about 52m. The maximum and minimum depths of this shaft are around 44 and 46m (see Figure 3, above). The shaft is divided into several sections by height, namely: lower and upper transport modules, apparatus floor and ventilation sections. An emergency exit is located near the ramps.

The structural design is represented by reinforced construction of cylindrical forms, a base plate, floor slab, concrete kentledge and spacing plates. Construction is top-down with support of different levels by means of concrete slabs with vertical supporting structural elements, a flight of stairs and staircase landings. Steel columns with barrette foundation are planned to be used as additional supporting structural elements during. All structures are made of reinforced cast concrete.

Left bank shaft

The design of the shaft on the left bank for dismantling the TBM is similar to the launch shaft in most respects. It has a cylindrical

form with a diameter 33m. Maximum and minimum depths of this shaft are about 42 and 43m. The construction is also divided into several floors by height criteria as: lower and upper transport modules, apparatus floor and ventilation sections. The emergency exit is again located near by the ramps.

The structural design of the construction area is presented by walling, base plate, concrete kentledge, vertical supporting structure elements, reinforcement frames and more over flight of stairs and staircase landings. Steel columns with barrette foundation are planned to be used as additional supporting structural elements at construction period by analogy with launch shaft. All structures are made of cast reinforced concrete.

Under water

Tunnel construction under the River Neva is executed with a slurry TBM.

Accepted technologies

The Orlovsky Tunnel, especially the solution of one tunnel bore with a diameter of 19m is a technically challenging project as this tunnel dimension hasn't been executed anywhere in the world before.

Taking into account that the tunnel will go under the River Neva where soil conditions are extremely difficult (mainly unconsolidated, soft, or very soft with inclusions of pebbles and boulders, and with some aquifers in the construction area) an active face support, and pressurised TBM is required to avoid water ingress,

Left: Figure 3, Section through the launch shaft on the right bank

Right: Figure 4, Cutaway perspective of the designed interior of the bored tunnel

large settlements or collapses. It was decided to use a single shield TBM. In this case precast segments will be installed in the tail of the TBM. Brushes sealing in the tail skin, and rubber gaskets between the segments in the longitudinal and radial directions assure a watertight system during construction. The investigation conducted showed that only a Mixshield (a slurry shield with an air cushion and stone crusher) fulfils the requirements.

Herrenknecht was chosen as a manufacturer for making innovation TBM shield with inner diameter 19m. A schematic drawing of the TBM and back-up is presented in Figure 5 (below, right).

Diaphragm walls

Monolithic reinforced concrete diaphragm walls (DWs) act as enclosing, antifiltration, supporting walls of the designed structure around launch and dismantling shafts.

DWs are planned to be built with the help of hydraulic grab equipment following technology, which presupposes flushing-up, the panel's line by using synthetic joint waterproofing tape 'Waterstop'. Grapple tongs with boom lengths of 2.8 to 4m will perform trenching.

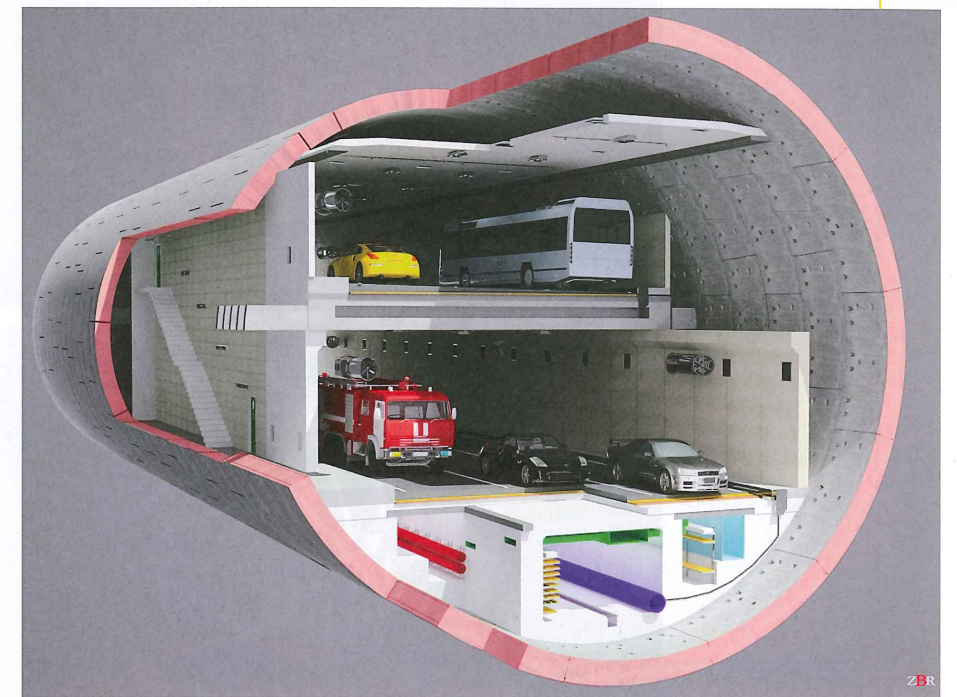
T-shape and G-shape grapple tongs will be used for quality formation of the diaphragm walls. A high quality of panel connections will be guaranteed by using 'Stopsol' removable end stops. The task sequence for construction of diaphragm walls is:

- Diversion (carrying over) of engineering subsurface services from the work area.
- Walling of the monolithic reinforced concrete foreshaft.
- Assembly of clay slurry plant.
- Fabrication of reinforcement cage panels for insertion in walls.
- Grapple excavation of development area under bentonite slurry protection.
- Replacement of bentonite slurry in excavation areas with freshly made or recycled mix.
- Setting of panel reinforcement cages in wall area using grapple tongs.
- Panel concreting.

After DW concreting the upper level of concrete (depth 400 to 600mm) with debris inclusions should be cut off.

Jet grouting

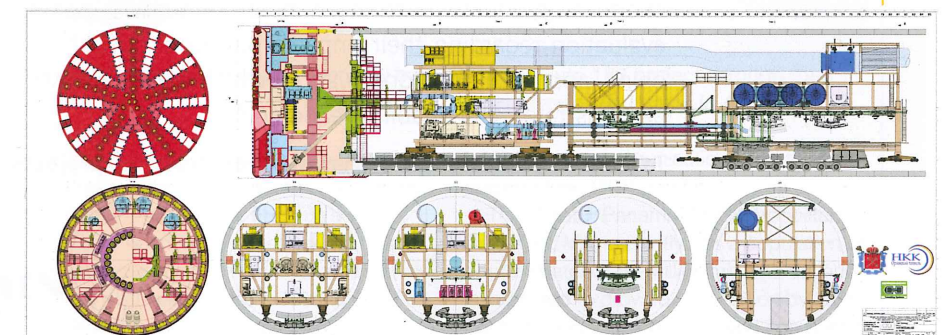
To ensure safe initial cutting and exiting of



the TBM at the start of tunnelling, installation of a vertical groundwater cut-off is planned beyond the launch shaft. As soils within the construction area are mainly unconsolidated, weak reinforcement of the ground is essential. Jet grouting will perform soil solidification between the groundwater cut-off and launch shaft.

Jet grouting involves erosion of soil by high pressure jets of grout (air-enshrouded grout and water) and the simultaneous injection of cement suspension grout into the disturbed soil by means of a jet monitor. This high-pressure jet is used for local ground break-up and mixing the soil to form 'soilcrete' with better characteristics. The created 'soilcrete' formation consists of the grout just jetted and existing soil particles as fine and coarse aggregates.

Below: Figure 5, Longitudinal section, cross-sections and cutterhead view of the world's largest Herrenknecht Mixshield TBM and back-up systems



The task sequence for jet grouting operation is:

- Preparatory work,
- Drilling of pilot borehole with washout at planned depth,
- Local soil break-up and mixing with a high-pressure jet of grout.

Conclusion

In the summer of 2011 Nevskaya Concession Company (NCC) received a positive decision from the Russian State Enterprise for the Orlovsky Tunnel construction giving the go-ahead.

The independent engineer COWI finalised checking of project documentation and approved the chosen construction and engineering methods.

The Orlovsky Tunnel shall be opened for operations and traffic in December 2015. ■



Boom to meet needs

The economies of Latin American countries are bucking the global trend and are the strongest they have been for many years. Nicole Robinson and Maurice Jones highlight some market factors and important projects in this increasingly important region for tunnelling

The countries of Latin America appear to be in various states of stability, whether in terms of economics, politics or security. The old image of weekly revolutions has long gone. Increased stability allows the exploitation of natural resources and, perhaps as a result, brings increased expectations among the populations, many of which tunnelling can help fulfil.

Unlike some other parts of the world, few underground construction projects in Latin America are designed primarily for prestige rather than to meet real needs, and yet records are being broken to provide power, water, access to mineral resources, and to improve transport and hygiene.

Transport led North

Focusing on the more northern countries in Latin America and Central Caribbean, the biggest source of demand for tunnelling comes from transportation. There are also notable sewer projects, and underground construction for hydroelectric projects.

Major metropolitan cities in Mexico, Panama and the Dominican Republic are developing subway systems. In the case of Panama City, Panama, and Santo Domingo, Dominican Republic, both cities are only working on the early stages of their systems. Mexico City has an established metro system, though with plenty more lines to build.

Panama

Compared to its northern neighbours, particularly the US, Panama has seen its economy strengthen, allowing it to invest in infrastructure projects. This reaps the



benefit of further bolstering its economy by creating jobs, while improving the quality of life for its citizens.

Public finances in Panama have proven to be resilient to the global crisis, according to a report presented by Panama's vice minister of economy, Frank De Lima. For example, revenues from the Panama Canal grew by 4.91 per cent from 2008 to 2009. This report, published in late 2010, found that transportation, among other sectors

Above: Ruta 150 project through the Ishigualasto Mountains in Argentina

including telecommunications and tourism, spearheaded GDP growth.

The Greater Panama City Metropolitan Area (GPCMA) currently has a population of approximately 1.58 million inhabitants, and is expected to grow to 2.36 million by 2025. For transport, citizens rely heavily on buses as well private automobiles. A systematic



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GRANDS PROJETS



Project Name: Metro Line 12
Location: Mexico City, Mexico
Purpose: Subway tunnel
Contractor: Ingenieros Civiles Asociados (ICA) with Grupo CARSO and Alstom
Value: USD 1.4bn
Dimensions: 8.7km of bored tunnel, 10.2m diameter
Timescale: Project start 2007, TBM launch Feb. 2010, expected completion 2012
Method: EPBM

Project Name: Tunel Emisor del Oriente
Location: Mexico City, Mexico
Purpose: Sewer tunnel
Contractor: Six lots among three different contractors: Ingenieros Civiles Asociados (ICA), Carso Infraestructura y Construccion and Lombardo Construcciones and Constructora Estrella
Value: USD 1.05bn
Dimensions: 62km long, divided into six lots, 7m diameter
Timescale: Project start 2008, completion 2014
Method: EPBM

Project Name: Corredor Bioceanico Aconcagua Base Tunnel
Location: Between Los Andes (Chile) and Lujan de Cuyo (Argentina) on Buenos Aires to Valparaiso railway
Purpose: International railway efficiency
Engineers: Geodata group (Turin)
Tunnel Length: 53km (later two x 53km)
Section: Phase One single-track single-bore, Phase two twin-bore single-track
Status: Conceptual studies
Method: Probably drill and blast. Possibly hard rock TBM

Project Name: Metro Line One
Location: Panama City, Panama
Purpose: Subway Tunnel
Contractor: Odebrecht and FCC Construccion
Value: USD 1.4bn
Dimensions: 7km of the 13km line are tunnels, 9.7m diameter
Timescale: late 2013
Method: TBM

Project Name: Panama City wastewater Treatment plant
Location: Panama City, Panama
Purpose: Wastewater conveyance tunnel
Contractor: Constructora Norberto Odebrecht
Dimensions: 8.7km of bored tunnel, 3.67m diameter
Timescale: TBM launched October 2010
Method: EPBM

Project Name: Ruta 150, a 24km stretch through Ishigualasto Mountains
Location: North-west Argentina
Purpose: Highway (Route 150)
Contractor: Jose Cartellone Construcciones Civiles (JCCC)
Tunnel Length: Six totalling 2.4km. Longest is 500m.
Section: 95m²
Status: In construction
Completion: 2013
Geology: Very mixed from running sand to hard limestone: types three to five.
Method: Mostly drill and blast with Atlas Copco XE3 and E2 C jumbos but some impact hammers and cutters in tunnel three.

Project Name: Line Two
Location: Santo Domingo, Dominican Republic
Purpose: Underground metro
Client: OPRET-the government agency for transportation
Value: estimated to be USD 770M
Dimensions: 11.5km for Phase 1, 9.6m in diameter
Timescale: Phase 1 is expected to open in 2012

Project Name: Ezequiel Zamora railway Puerto Cabello to La Encrucijada Branch
Location: Aragua and Carabobo, Venezuela
Purpose: Long-distance rail
Engineers: Instituto de Ferrocarriles del Estado (IFE) (National railways administrator)
Tunnel Length: 28km in total inc. 7.8-km Barbula Tunnel (claimed longest in South America so far)
Status: In construction
Completion: Due December 2011

Project Name: El Teniente New Mine Level Project (NMLP) (part)
Location: 80km South of Santiago, Chile
Purpose: Underground copper mine development and deepening
Client: Codelco (Chile national mining corp.)
Contractor: Vinci Construction Grands Projets/Soletanche Bachy
Engineers: Hatch Mott MacDonald and Vinci
Value: USD 400M (total project USD 3.28bn)
Tunnel Lengths: Two x 9km plus two x 6km (total 30km)
Section: Average 65m²
Start: October 2011
Geology: Strong volcanic plus metamorphic with weak fault zones
Method: Multiple Robodrill drill and blast rigs

Project Name: Sao Francisco River Transfer
Location: States of Pernambuco, Ceara, Paraiba and Rio Grande do Norte around Cajazeiras, north-east Brazil
Purpose: Water transfer for irrigation etc
Contractor: JV of Toniolo Busnello, Ferreira Guedes and Construcap
Tunnel Length: Several totalling 33.7km, (Longest is Cuncas I at 15.257km on Trecho II - North Axis), plus 20km of pipelines, in a total transfer system of 722km
Section: Various
Status: In construction
Method: Mainly Sandvik roadheaders

Project Name: Buenos Aires Metro Line G
Location: Buenos Aires, Argentina, east-west around north of city centre from Cid Campeador to Retiro
Purpose: Metro
Client: Subterraneos de Buenos Aires (SBASE), operated by Metrovias
Tunnel Length: 7.3km with 11 stations (later another 5.2km with four more stations)
Start: 2012
Completion: None official

Project Name: Buenos Aires Metro Line One
Location: Buenos Aires, Argentina, north-south to west of city centre between Plaza Italia and Parque Chacabuco
Purpose: Metro
Client: Subterraneos de Buenos Aires (SBASE), operated by Metrovias
Tunnel Length: 6.6km with nine stations (later another 6km with nine stations)
Completion: None official

Project Name: Sao Paulo Metro Line Four section extension
Location: Sao Paulo, Brazil.
Purpose: Metro
Client: Companhia do Metropolitano de Sao Paulo (Via Quatro - PPP operator)
Contractor: Comargo Correa
Tunnel Length: 2km with two stations (total route 14.3km)
Status: In construction
Completion: 2012. Whole line to be operational in 2014
Method: Cut and cover plus NATM

Project Name: Sao Paulo Metro Line Five
Location: Sao Paulo, Brazil to south-west of city
Purpose: Metro
Client: Companhia do Metropolitano de Sao Paulo
Tunnel Length: 14km of 22.4km total
Status: In construction including five stations. In planning and design six stations.
Completion: First section length completed 2002. Whole 2011-12

Project Name: Sao Paulo Metro Line Six
Location: Sao Paulo, Brazil through city centre between Brasilandia (north-west) and Vila Prudente (south-east interchange)
Purpose: Metro
Client: Companhia do Metropolitano de Sao Paulo (possible PPP)
Contractor: None yet
Tunnel Length: 19km
Status: In design, planning and property expropriation
Completion: 2013-2016

Project Name: Sao Paulo Metro Line 15
Location: Sao Paulo, Brazil, between Vila Prudente interchange (west city) and new Tiquatira station in north-east city
Purpose: Metro
Client: Locally based Companhia do Metropolitano de Sao Paulo
Tunnel Length: 10km with nine stations
Status: Projected
Completion: 2013

Project Name: Sao Paulo Metro Line Line 18
Location: Sao Paulo, Brazil, north-south through city centre between Tamanduatei station and the new Estrada dos Alvarengas station
Purpose: Metro
Client: Locally based Companhia do Metropolitano de Sao Paulo
Contractor: None yet
Tunnel Length: 20km with 16 stations
Status: Being studied
Completion: 2017





Above: Preparatory work on Panama City's Line One

overhaul was needed to avoid the collapse of vehicle traffic by 2015, according to Panama's ministry of economics.

By 2014 the region hopes to welcome its first metro line. A consortium of Constructora Norberto Odebrecht, Fomento de Construcciones y Contratos (FCC) and Alstom won the USD 1.5bn contract, which includes 7km of tunnels and five underground stations. The rest of the 13.7km line will be constructed on viaducts with six aerial stations. Two Herrenknecht EPBMs of 9.6m diameter are excavating the tunnels.

By 2035, the city plans to have an entire underground transport system—the pet project of President Ricardo Martinelli. At an acceptance ceremony for the Line One TBMs at Herrenknecht's facilities in Schwanau, Germany, Martinelli was already announcing the tender for Line Two of the city's metro.

In Santo Domingo, the Dominican Republic's government transport authority, called Opret, also has a master plan for phased construction of a metro system. Line One started commercial operations in January 2009, with the service running north and south.

Line Two, which will run east to west across the city, entirely underground, is being delivered in two phases. Opret expects the first phase of 11km in length to open in 2012.

Adding capacity

Mexico City has 11 metro lines already in operation, with the development of the initial lines dating back to the 1960s. Line 12 will run for a total of 25km when it opens next year, and 8.7km are being tunnelled. The consortium of Ingenieros Civiles Asociados (ICA) with Grupo Carso and Alstom is using a Robbins EPBM to construct the 10m-diameter subway—the first ever to be used on one of the city's metro line projects. The final breakthrough on Line 12 is expected in late 2011 or early 2012, according to Robbins.

The city has a master plan, developed back with the first metro lines in the 1960s, and it lays out the basis for five more lines to be built. This planning document originally called for the entire Line 12 to be built by cut and cover construction, which would pose a massive time constraint, widespread disruption and exceed the city's budget. Down the road, as the city—one without much underground infrastructure—finesses its plans for future metro development there is likely to be even more demand for tunnelling.

South America

South of the Canal, the tunnelling rush is led by the larger countries and economies, namely Brazil, Argentina and Chile, although Colombia, Ecuador and Venezuela also have major projects.

In terms of individual projects and contracts, the busiest end use sector is metro construction, with Sao Paulo and Buenos Aires, among others, engaged in major metro network expansion schemes, elevated and at surface level as well as underground. The need is most marked in megacities like Sao Paulo where road transportation could take several hours to pass from one side of the city to the other, decreasing business efficiency and inconveniencing the population. It is arguable whether better mass transit schemes tend to increase urban sprawl, but at least they can deal with more immediate problems.

Transport in Brazil has been brought into strong focus with the award of the 2014 World Cup. Fifa authorities have expressed concern about apparent delays in the development of some infrastructure projects including the long-term dream of South America's first high-speed rail link between Sao Paulo and Rio de Janeiro which will now miss the showpiece event. For the third time bidding has stalled—this time there were no bidders. Potential suppliers were put off by unrealistically low estimates and a frequently tumultuous

political background. The project includes around 90km of tunnels and still claims to be on track.

Hydropower

South America has long been associated with major hydroelectric projects with its usual abundance of water and topographical differences in elevation. But the region's appetite for power has never been greater, especially with the increase in world prices for fossil fuels that often have to be imported. Beyond the economic case, environmental considerations in reducing dependence on carbon-based power also make hydropower attractive if suitable schemes can be devised. Underground construction increases the options for designers.

More efficient long-distance travel is also a demand to reduce the dependence on seaborne heavy freight via the Panama Canal or Cape Horn. In this, mountain ranges, and in particular the Andes, have been historical barriers. In efforts reflecting, to some extent, the development of trans-Alpine travel in Europe, better rail and road routes are being driven through this major range, including base tunnels like that planned for the Buenos Aires to Valparaiso railway (see feature, page 28).

Mining in South America ranges from small 'artisan' and largely unregulated workings to some of the biggest holes dug in the world. The bigger enterprises or mining regions have long been a stimulus for tunnelling for railways as well as for the mining itself. Now, with the increased international demand for raw materials, particularly from Asia, some of the richest deposits exploited by opencast mining are being developed underground at greater depths. This can often necessitate major tunnelling projects as well as shaft sinking to gain access to the deeper reserves. The development of a new, deeper level in Chile's El Teniente copper mine is a prime example of this.

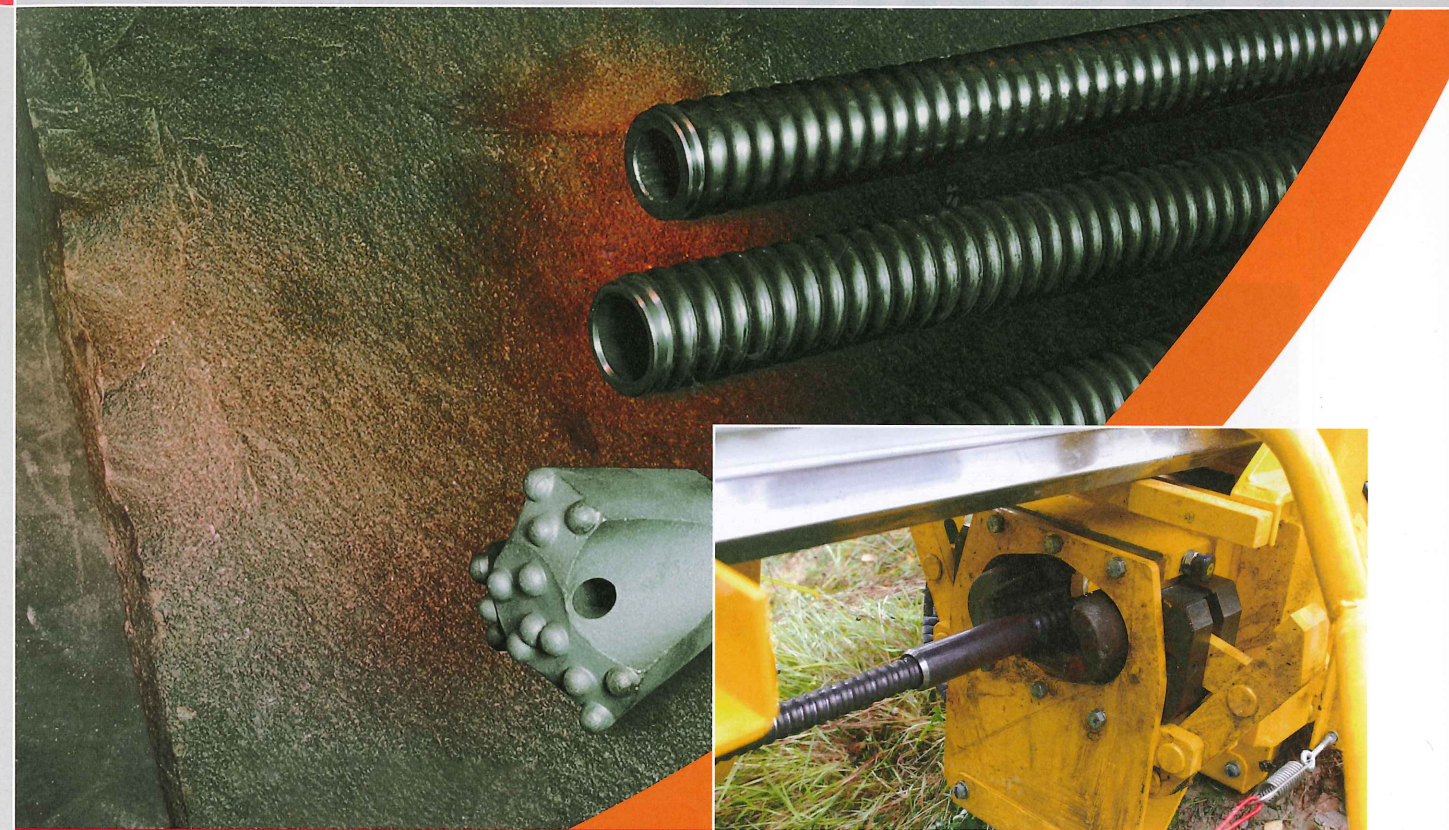
Environment

In recent decades South America has become a target for much environmental concern, particularly from outside of the region, but there are strong indications that authorities are now paying attention to these concerns, particularly as funding bodies often have environmental criteria written into loan agreements. Even so, mining and hydro projects in particular have become targets for environmental campaigners, such as with Brazil's Sao Francisco water diversion project, even though it should benefit many farmers. ■



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Mexico's mega dig



Work is underway on Mexico's largest infrastructure project: the Emisor Oriente. Robbins vice president Joe Roby and Mexico general manager Roberto Gonzalez explain how the wastewater tunnel will save a sinking city

Mexico's largest infrastructure project is a 62km long emergency wastewater pipeline being built to prevent flooding in the downtown area of the capital. Ground settlement in Mexico City has caused the existing gravity feed wastewater system, built in 1975, to lose its slope. Much of the main pipeline, Emisor

Central, is severely corroded and at high risk of failure, which would cause up to 5m of wastewater to flow into Mexico City's surface streets.

To remedy the problems, the Mexico National Water Commission (Conagua) released a contract for a 7m internal diameter, long pipeline known as the Emisor Oriente Wastewater Tunnel. To meet

Above: The 62km long wastewater tunnel project features 23 shafts up to 150m deep

the demanding schedule, six 8.93m diameter EPBMs were required.

Mexico City, a metropolis of more than 22 million people, is sinking at the rate of 100mm per year. The world's second

largest city was founded by the Aztecs in the Valley of Mexico, on what was once an island in the middle of Lake Texcoco. Spanish conquistadores later drained the lakebed using a system of canals, but the soft lake clays remained underneath the city's infrastructure. A combination of a booming population and compression on the city's main sewer lines has necessitated the creation of the Emisor Oriente tunnel.

Mexico City's wastewater system is almost exclusively served by the Emisor Central, a 68km-long line built in 1975, which has lost capacity over the past three and a half decades, as ground settlement caused a decrease in slope in the gravity sewer line. Severe corrosion and nearly continuous groundwater infiltration also made it impossible for the Emisor Central to be inspected and maintained between 1995 and 2008.

Once inspection was made possible, it was found that the overall system capacity had been reduced by 40 per cent since 1975—from 280m³/sec to 165m³/sec in 2008. Over the same time period the city's population more than doubled from 10 million to more than 20 million inhabitants, increasing demand on the system.

Despite its obvious need, the project is not without some controversy, particularly for the valley's farmers. Mexico's untreated wastewater flows through a system of open canals that feed much of its farmland. The lush bounty of crops is the direct result of fertilisation by the so-called 'black waters', which will be stopped by the commissioning of the new Emisor Oriente line and wastewater treatment plant.

Project description and location

Conagua recommended immediate construction of a new line to help supplement the struggling system (see Figure 1, right). The Emisor Oriente will increase the city's current sewer capacity by 150m³/sec once complete and will carry wastewater from Mexico City to several water treatment plants currently under construction in the state of Hidalgo.

The construction of the line was divided into six lots (see Figure 2, right)—lots one, two and five under Mexican contractor Ingenieros Civiles Asociados (ICA), and lots three and four under Carso Infraestructura y Construcción. Lot six is being constructed by Lombardo Construcciones and Constructora Estrella. All six lots will be bored by EPBM. Robbins was chosen to supply lots three, four and five, which will all

be bored using three EPBMs.

Geological conditions

Original conditions

Original geology was based on multiple borehole tests conducted along the tunnel length. The geology of the Valley of Mexico is highly complex, with large boulders up to 600mm in diameter predicted throughout the drives. This particular set of geologic characteristics is found only in Mexico and in certain areas of Japan.

Actual geologic conditions

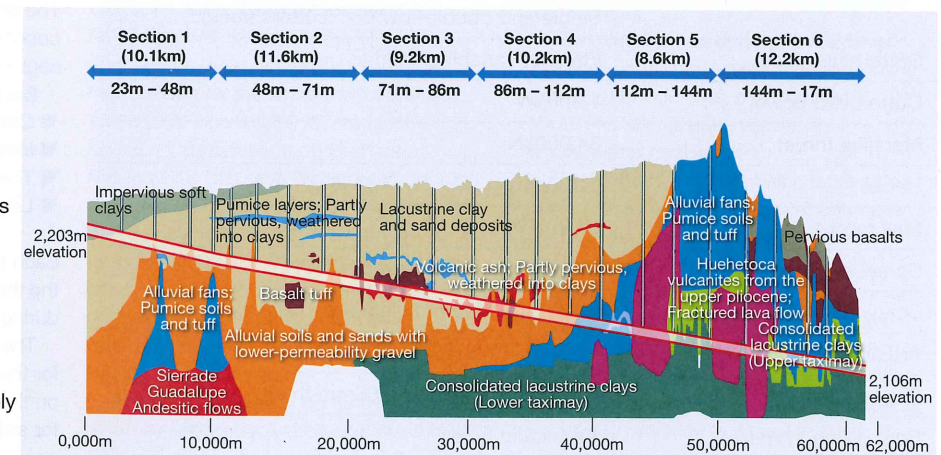
Despite rigorous testing, excavation of the shafts in 2009 and 2010 revealed much more difficult geology than originally anticipated (see Figure 2, page 24). These changes in geology resulted in some modifications to the designs of the machines, depending on the ground conditions in each lot. Lots three and four were found to include abrasive basalt, volcanic rock and higher water pressure.

Shaft excavation

The project includes the construction of 24 shafts starting from 23m and going to 150m deep. Shafts five, 10, 13, 17 and 20 have the diameter of 16m, while the rest are 12m in diameter.

The shafts were constructed by using three main methods: slurry walls, traditional excavation and hydraulic hydro roadheader for the most difficult geology. Many of the shafts were constructed by both methods—using the slurry wall up to a certain depth and after that the traditional method.

With the exception of shafts constructed by the hydro roadheader, the slurry wall could only be constructed up to 46m, since it was limited by the capacity of the guided clamp. Shafts deeper than this had to be cut by the traditional method after 46m.



The traditional method consists of excavating 1.5m, then installing steel rebar mesh, ring beam and shotcrete. After each level is secured another 1.5m excavation can start.

After the primary lining is finished, a secondary lining is installed by using a sliding form. This secondary lining gives the shaft more structural rigidity.

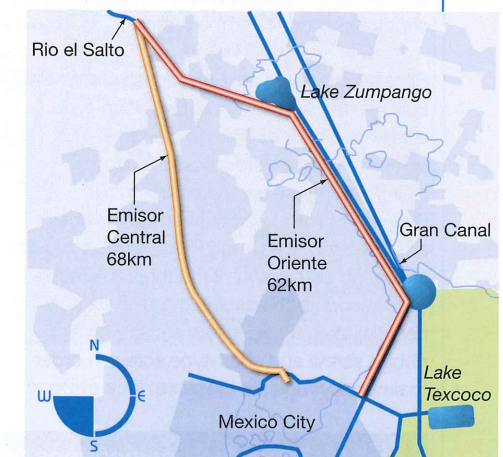
Machine design

The three EPBMs supplied by Robbins are 8.93m in diameter. All of the machines are designed for the mixed ground conditions.

Cutterhead design

The machines are using mixed ground, back-loading cutterheads for the variable geology. The design allows for a change in cutting tools between sections of soft ground and rock.

The seven-piece, spoke-type cutterheads consist of six outer segments



Above: Figure 1, Mexico City's Emisor Oriente Pipeline stretches 62km
Below: Figure 2, the revised geology at Emisor Oriente includes longer sections of abrasive basalt and volcanic rock



plus a hexagonal-shaped centre section to maximise the opening ratio of the face. The machines were designed with the largest possible opening ratios to ensure a smooth flow of muck into the cutterhead chamber.

Crews can switch out between high pressure, carbide knife-edge bits and 17in carbide disc cutters depending on the ground conditions. A number of small shafts, spaced every 3km between the larger launch shafts, will be used to perform cutter inspection and changes. Specialised wear detection bits will lose pressure at specified wear points to notify crews a cutting tool change is needed. The knife edge bits are arranged at several different heights to allow for effective excavation at various levels of wear.

The design also allows for bearing and seal removal from either the front or back of the cutterhead. There are 25 injection ports spaced around the periphery of the machine that can be used for injection of various additives depending on ground conditions, and for probe drilling.

Screw conveyor and muck removal

Each machine is fitted with a ribbon-type screw conveyor 900mm in diameter. The screw conveyors allow boulders up to two-thirds the screw diameter (up to 600mm) to travel up the shaft, where they are disposed of through a boulder collecting gate. Each of the three machines may encounter pressures of up to six bar, necessitating a two-screw setup with a ribbon screw and shaft-type screw in order to smoothly regulate pressure.

Muck is deposited from the screw to a rubber belt conveyor mounted on the trailing gear, which transfers to a side-mounted continuous conveyor. The continuous conveyor carries the muck to a 150m long vertical belt conveyor located at the launch shaft.

Once at the surface, a radial stacker deposits muck in a kidney-shaped pile for temporary storage. This system will be used on all three lots.

The three continuous conveyor systems, also provided by Robbins, consist of 762mm wide fabric belt at a 3,200m length and 900 tonnes per hour capacity. Approximately 22 per cent of the conveyor systems will be travelling through curves, with a minimum 700m curve radius. To better handle curves, the systems will use self-adjusting curve idlers. These idlers pivot to accommodate changing load tensions around curves. The pivoting action is favourable because it does not unnecessarily alter the carrying capacity of the conveyor or the belt tension.

Articulation

For accurate tunnelling through curves, each machine features active articulation. Active articulation engages articulation cylinders between the front and rear shields to steer the machine independently of the thrust cylinders. The process allows the thrust cylinders to react evenly against all sides of the segment ring during a TBM stroke in a curve. Typical configurations, which use flat joints to articulate the shield, are

capable of making two to three degree curve adjustments over the length of the segment or stroke.

Another reason active articulation was chosen for this project was the risk of segment deformation, or cracking. A common cause of project delays, deformation occurs most commonly when the passive articulation system is used in curves. Passive articulation does not use articulation cylinders independent of the machine's thrust cylinders, so the TBM reacts against sides of the segments unevenly in curves.

Modifications to the machine design

Several modifications were made to the machines to accommodate the longer sections of hard, abrasive rock coupled with high water pressures that were discovered during shaft construction. These modifications include:

- A two-person man lock added to all of the machines, capable of withstanding the higher pressures. With abrasive ground, more frequent cutter changes are anticipated.
- All machines were outfitted with a redesigned pressure bulkhead for high water pressure.
- Hard facing added to each turn of the screw conveyor and the conveyor casing on the lot three TBM, in order to withstand abrasive hard rock.
- Hydraulically operated boulder collecting gates replaced manual gates on the machines, to make removal of numerous boulders more efficient.
- A high-pressure bentonite injection system added to the lot four machine for ground conditioning.

Concrete tunnel lining

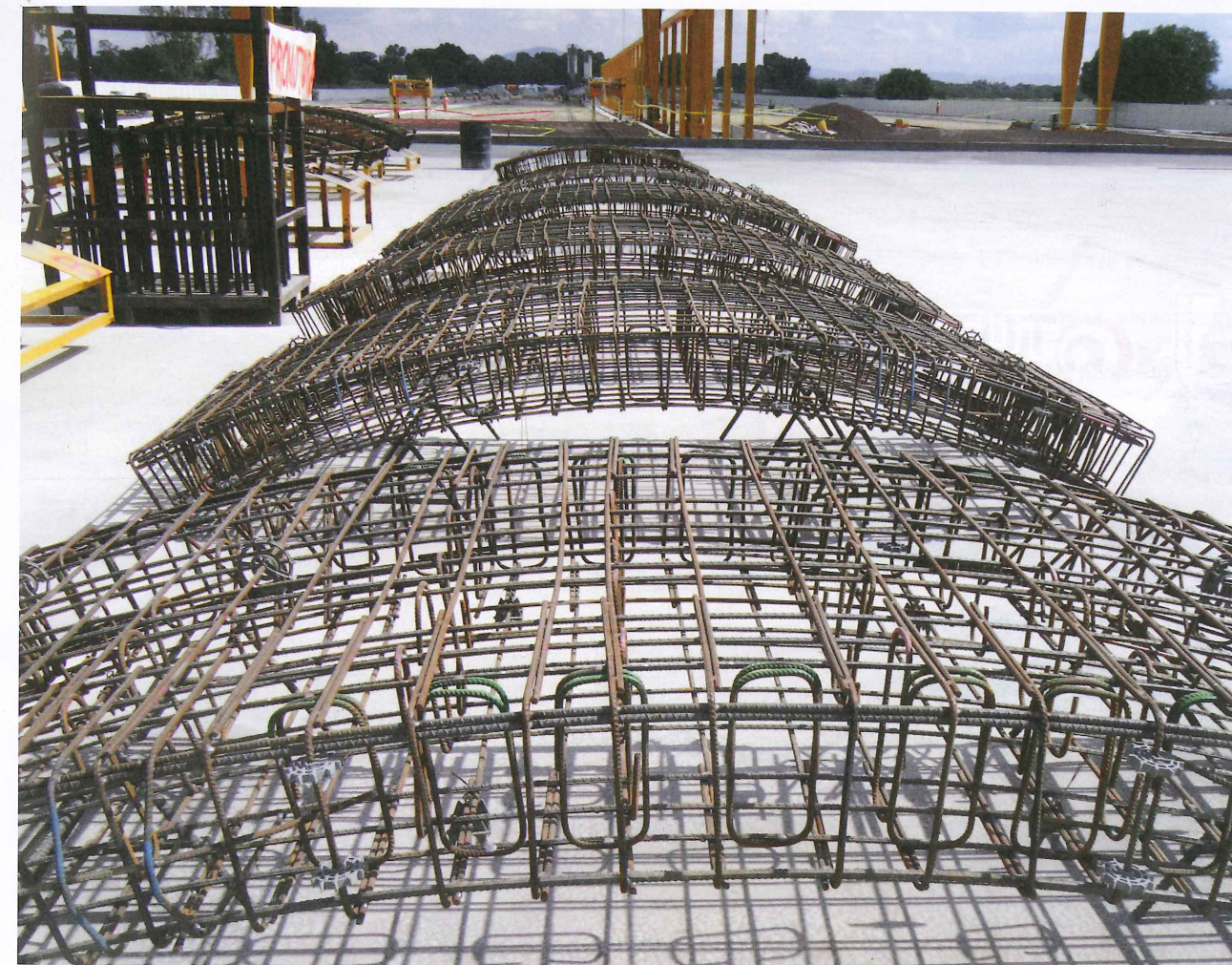
The tunnels are being fully lined with concrete segments. After an excavation cycle of the TBM, a concrete segment ring is assembled at the tail shield of the EPBM. The primary lining consists of universal concrete rings designed as having seven segments plus a key.

Each ring has the following dimensions:

- Outer diameter: 8.6m
- Inner diameter: 7.8m
- Thickness: 0.4m
- Length: 1.5m (conical)

Each segment ring is designed to receive the thrust cylinders of the TBM evenly during a push.

The segment design also includes ports for the pickup system of the segment hoist on the TBM; these same ports can be used for secondary grouting through the



segments if necessary.

Reinforcement of each concrete segment is made out of rebar, which is designed to resist the varying earth pressures on the tunnel alignment. For deeper tunnel sections the rebar has been designed as a very close-knit pattern.

Segment plants

To be able to guarantee the supply of the segments, two segment ring plants were built, along with one plant that was already working. The production is set at 567 segments a day, equivalent to 81 complete segment rings, to be able to comply with the demand of six TBMs operating at once.

During the course of tunnelling each plant will fabricate 14,000 segment rings, and will use 120 workers daily. Each segment requires six to eight hours to complete. The total lining of the 62km-long tunnel will require a total of 42,000 complete segment rings.

Secondary lining

A secondary lining will be installed after

Above: Rebar reinforcements for the tunnel's concrete segments are designed to resist varying earth pressures

finishing each drive of the tunnel. The concrete will have a thickness of 250mm. The secondary lining will be installed by means of a telescopic continuous casting form, in order to avoid joints in the concrete lining.

Current site 2011 operations

As of October, the first of the EPBMs originally destined for lot four had been fast-tracked for launch at the lot one site. The critical lot one site, located in the Ecatepec area outside of downtown Mexico City, has seen widespread flooding during each rainy season—a predicament that delayed the launch of a different machine at the site for six months. In order to compensate for time lost, lot one contractor ICA began boring a 5km section from the opposite direction using a different manufacture of machine.

A pumping station is currently being built at the severely affected lot one site, which

will go into service before the rest of the wastewater line is complete. The finished lot one section will then be sealed off to allow the excavation to continue. The water will be diverted into the Emisor Oriente, then pumped downstream into a part of the Gran Canal less affected by loss of slope and erosion.

The machine has to date bored about 279 rings, or 418m, in very soft and clayey geology. No boulders, sand or other abrasive material have yet been encountered on the drive.

The lot three machine being assembled at shaft 10 is about 50 per cent complete with its assembly. Back-up gantries have been assembled at the surface, and lowering of the newly redesigned machine components including the man lock and bulkhead is proceeding as planned.

Launch of the lot three machine is scheduled for this month, with assembly of the lot five machine in January 2012. ■

Table 1: Specifications for Emisor Oriente EPBMs

| 8.93m Diameter EPB TBMs | |
|----------------------------|--|
| Excavation diameter | |
| Cutterhead for soil | 8,910mm |
| Cutterhead for rock | 8,930mm |
| Main cutting tools | Special knife-edge bit (soil) Single and double-row disc cutters (rock) |
| Cutterhead drive | Electric, variable speed |
| Cutterhead power | 1,900kW |
| Machine thrust | 84,000kN |
| Stroke | 2,300mm |
| Max torque | 17,900kNm |
| Screw conveyor #1 | Ribbon type, 900mm diameter |
| Screw conveyor #2 | Shaft type, 900mm diameter |
| Articulation | Active |
| Segments | Reinforced concrete, 400mm thick |
| Back-filling system | Two-liquid type |



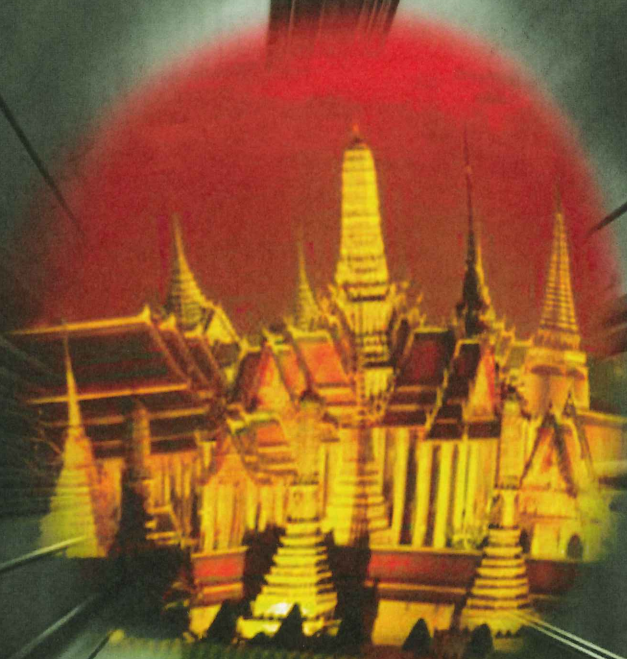
WTC 2012

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18 - 23 May 2012

"Tunnelling and Underground Space for Global Society"
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Under the theme "Tunnelling and Underground Space for Global Society", WTC2012 Bangkok will call together the tunnelling and underground space community in the Southeast Asia region to set up a forum with the World Tunnelling Society. Besides being involved in an excellent forum for technical discussion, exchanging ideas and sharing experience, participants will have the opportunity to meet with high-level industry leaders, academics, developers and decision makers from the region and various parts of the world.

This is the first time that Thailand will host the ITA-AITES World Tunnel Congress and 38th General Assembly, one of the most privileged congresses in the construction industry. The host city, Bangkok, is one of the world's favorite tourist destinations. In addition to its unique culture and exquisite architecture, the capital of Thailand has much to offer to the Congress delegates.



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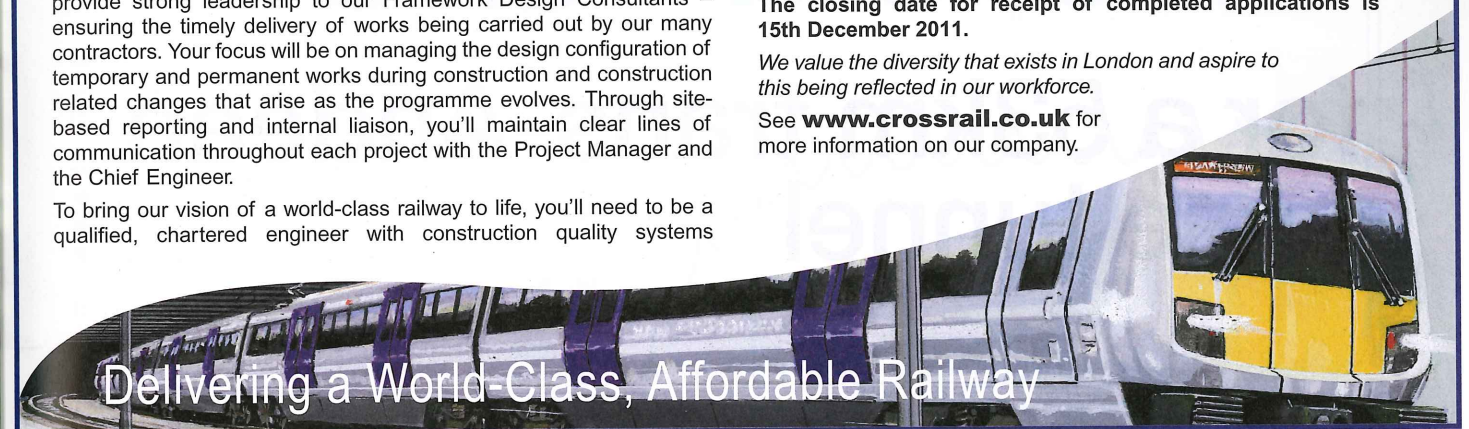
experience and a solid understanding of design delivery and project control processes. A background in managing similar large-scale infrastructure projects is vital. What's more, you must combine knowledge of site-based ES&H procedures with construction and design experience.

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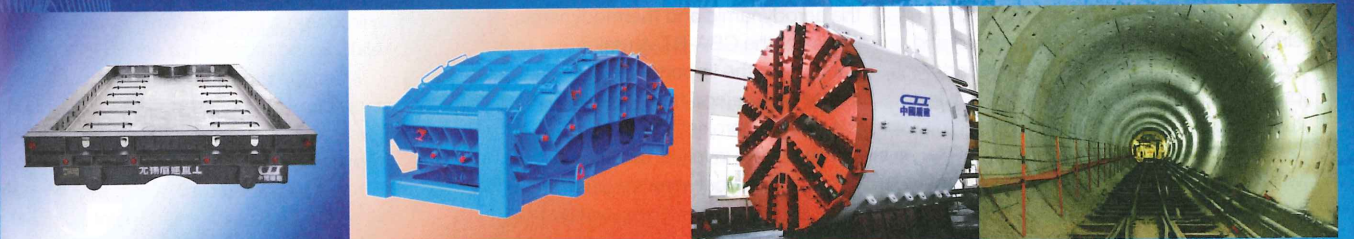
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Ventilation and climate

for a 53km trans-Andean base tunnel

This paper, adapted from that presented at the Underground Construction conference in London, UK, in April by Andrea Krpo, describes ventilation concepts, including fire control, for a proposed rail base-tunnel through the Andes to improve transport between Argentina and Chile. Co-authors are Mattia Ferrazzini, Michael Flueckiger and Peter Reinke, all of HBI Haerter of Berne, Switzerland

The project Corredor Bioceánico Aconcagua (CBA) is a future rail line between Chile and Argentina with a length of about 215km. An important component of the CBA project is the 53km long base tunnel (BT), which will allow crossing the Andes most directly and with moderate inclination (Figure 1, below).

The construction of the BT is divided into two different phases. First a single-tube, single-track tunnel will be constructed and operated. In a second phase, a second parallel tube will be added, so that a twin-tube, single-track rail tunnel will be available. While in the first phase the BT will be used almost exclusively for freight trains, in the second phase passenger trains may pass as well. The future double-track system of Phase Two will allow the traffic of more than 160 freight trains every day corresponding to 70Mt of goods in both directions each year, and an appropriate number of passenger trains.

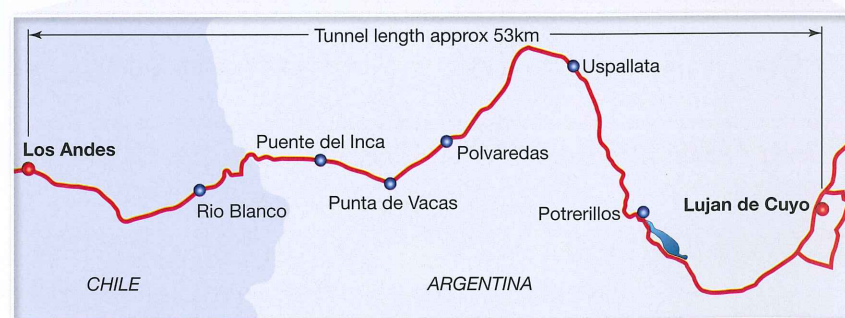
Introduction

High rock temperatures and a substantial height difference of the portals of the BT require particular measures to assure an appropriate climate, reasonable aerodynamic

conditions and a sufficient air-exchange by natural and mechanical ventilation. Here these aspects are clarified for all modes of operation (normal, emergency, maintenance and congested). The design objectives and the proposed solutions are presented. One-dimensional numerical simulation models are used for the analysis of the aerodynamic and thermodynamic issues of the CBA-BT. A major outcome is the important role of tunnel climate and tunnel ventilation in the CBA-BT project.

The project involves restoring a former rail line between Chile and

Below: Figure 1, the Corredor Bioceánico Aconcagua base tunnel (CBA-BT). Detailed view beneath



Argentina. The system will connect the cities of Los Andes (Chile) and Luján de Cuyo (Argentina). The future railway network will be of importance as it will offer a direct rail connection between the Atlantic (Buenos Aires) and the Pacific Ocean (Valparaíso). The BT will also guarantee higher train speeds.

The cities of Los Andes and Luján de Cuyo will be provided with terminals for shuttle trains, as well as for the management of customs operations.

With the planned traffic the CBA may become the most important railway line for goods transportation of South America in the future.

Due to its exceptional length, the BT requires particular measures to ensure:

- An appropriate climate,
- Reasonable aerodynamic conditions and
- Sufficient air-exchange by ventilation.

This paper aims to analyse the aerodynamics and the climate for the CBA-BT and to present a ventilation concept. It shall confirm the feasibility of the tunnel ventilation system (TVS) for Phase One and Phase Two of the project regarding the normal, maintenance, congested and emergency modes of operation.

Tunnel system

The 53km-long CBA-BT has an inclination of up to 17 per thousand (17:1,000). There is no peak point in the middle part of the tunnel but a mostly continuous positive gradient from the Chile portal in direction of the Argentina portal. The different heights of the two portals generate a pressure difference, which depends on the difference between the tunnel and the outdoor air temperatures. This results in a predominant air flow along the tunnel from portal Chile to portal Argentina (natural draft effect).

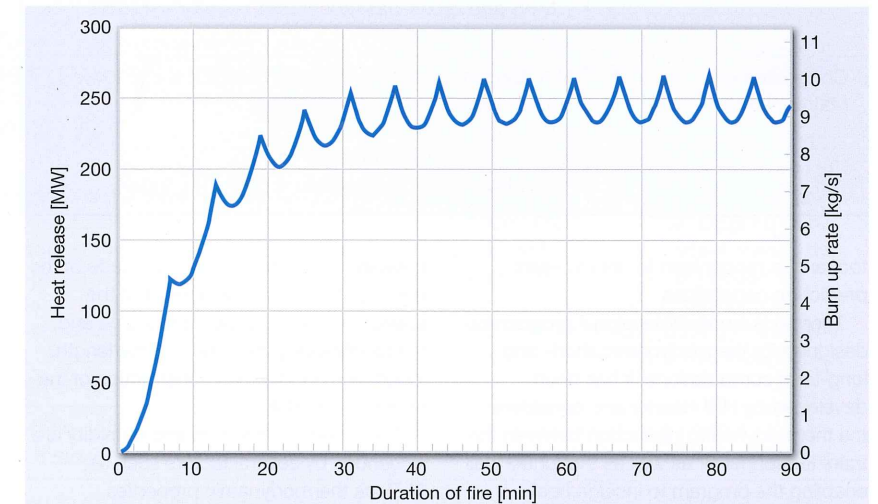
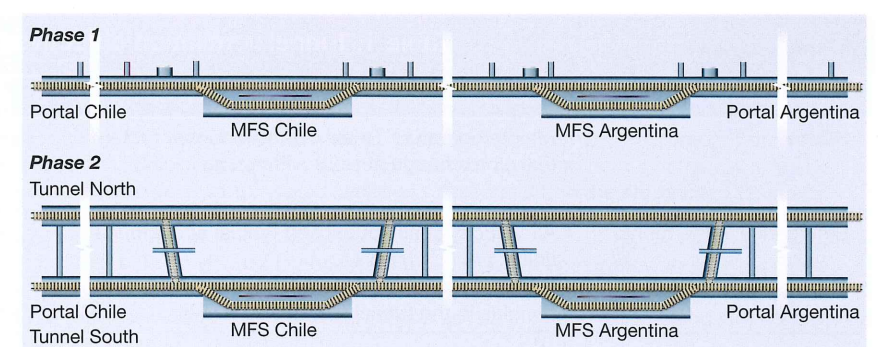
Existing international norms, guidelines and recommendations shall be followed to plan the civil layout of the CBA-BT. Some safety related standards are:

- Union International des Chemins de Fer UIC 779-9 (2003).
- United Nations (2003).
- European Community Technical Specifications of Interoperability (2008).

At its final stage (end of Phase Two), the CBA-BT will consist of:

- Two single-track rail tunnels.
- Cross passages every 500 m connecting the rail tunnel tubes.
- Two multifunction stations (MFS) with a distance of 17 km between them.

An illustration of the CBA-BT for the two



construction phases is provided in Figure 2 (above, top).

Rolling stock

Phase One of the CBA-BT is foreseen for the operation of freight trains only. The use of passenger trains is planned for Phase Two when the second tube will be in use.

Two different types of freight trains are considered:

- Shuttle trains: transport of road vehicles, i.e., trucks.
- Qualified freight trains: mixed stock for transport of goods.

Velocities of 100km/h are foreseen for freight trains and 120km/h for passenger trains.

The magnitude of a possible fire on a train may vary a lot depending on the type of goods that the freight train is transporting. As indicated in Figure 3 (above), fires on freight trains could reach a maximal heat release rate (HRR) of approximately 250 MW.

Due to the extreme release of energy, comparing different reference tunnel projects is not relevant for the ventilation equipment needed to handle fire on freight trains. This consideration is generally planned by considering a maximum HRR of



Top: Figure 2, Construction design for the two operating phases Above: Figure 3, heat release rates on freight trains

20MW (expected power on typical passenger trains).

Methodology

The following methodology has been considered to study the TVS:

- Setting of the concept.
- Prove the feasibility of the designed TVS by numerical simulations.
- Identify the consequences for civil design of the specified TVS.

Numerical tools

For the analysis of the aero- and thermodynamic issues of the CBA-BT, two numerical tools with their latest versions are used: Thermotun and Thermo.

Thermotun is a program for aerodynamic simulations of rail tunnels developed by A.E. Vardy. It is based on a one-dimensional method of characteristics and is validated by several measurements. The program allows for modelling the performance of the TVS, including fans and dampers, or to calculate the dispersion of pollution and heat.

Thermotun is an internationally-approved



Table 1: Tunnel ventilation objectives

| Operation mode | Tunnel ventilation objective | Comments / References |
|--------------------------|--|--|
| Normal | <ul style="list-style-type: none"> • Max temperature $T_{max} < 35^{\circ}\text{C}$ in tunnel system • Full air exchange at least within time $t < 24\text{h}$ | <ul style="list-style-type: none"> • Gotthard Base Tunnel (GBT) • Lotschberg Base Tunnel (LBT) • Brenner Base Tunnel (BBT) |
| Emergency in the tunnel | <ul style="list-style-type: none"> • Air velocity shall not exceed typical acceptance limits: $v_{Ai} < 11\text{m/s}$ • Critical velocity v_c must be achieved in the train annulus in the tunnel therefore $v_c < v_{Air}$ | <ul style="list-style-type: none"> • NFPA 130 (2010) • Lyon – Turin Ferroviaire (LTBT) • Pir Panjal (single-track; single-tube) • Young Dong (single-track; single-tube) |
| Emergency in MFS | <ul style="list-style-type: none"> • Air velocity v_{Air} in the emergency exit doors in MFS and cross-passages: $2\text{ m/s} < v_{Air} < 11\text{ m/s}$ | <ul style="list-style-type: none"> • GBT • LBT • BBT |
| Congested or Maintenance | Not relevant for sizing of equipment but the following aspects need to be ensured later: <ul style="list-style-type: none"> • Pollution below health limits • Occupational health requirements • Wet Bulb Globe Temperature (WBGT) – Index | <ul style="list-style-type: none"> • GBT • LBT • BBT |

tool and is recognised for its excellent prediction capabilities.

Thermo is a one-dimensional programme designed for thermodynamic short- and long-term computations. It has been developed by HBI Haerter and considers the thermodynamic interaction between the train, the tunnel air as well as the tunnel wall enabling the program to include heat transfer from rock and trains. The output from Thermo contains the temporal and spatial distribution of temperature and humidity as well as the heat balance of the trains in the tunnel system. Thermo has been validated against other thermodynamic programs (e.g., a program of the SNCF [French Railways] for the Alpetunnel Project between Lyon and Turin) and with measurements for the Furka tunnel. Thermo has been applied for numerous tunnel systems.

TVS functional requirements

In normal operation design, normal trains pass through the CBA-BT according to schedule. When a train enters the tunnel, a pressure wave is generated. This propagates at the speed of sound as a compression wave (+) along the tunnel (piston effect). When the wave hits the exit portal, it is partially reflected and travels back as an expansion wave (-). Further reflections at portals, cross-sectional area changes or trains might lead to various compression or expanding waves oscillating in the tunnel. These pressure waves together with the pressure differences along the moving train act on the train structure, the tunnel wall, the installed equipment and the people

travelling on the train. The magnitude of the pressure fluctuations is a result of the speed, the cross-section, the shape and the roughness of the train and the length, roughness and the civil construction of the tunnel and portals.

The tunnel temperature and humidity are influenced by several factors such as:

- Rock thermodynamic properties.
- Heat load from the rolling stock and electrical installations in the tunnel.
- Water through the tunnel walls.
- Meteorological conditions at the entrance portal.

During normal mode of operation, the air quality, temperature and humidity are controlled by the train-induced piston effect or (if necessary) by forced ventilation provided by the TVS.

In congested or occasionally disturbed operation, trains need to stop due to track blockage, power cut-off or other reasons. Staying stationary for several minutes or even hours might lead to an unacceptable temperature rise because of release of waste heat (from air-conditioning or cooling facilities). During the congested mode of operation, the TVS is used to supply ambient air and remove (with respect to exhaust) waste air. The amount of fresh air that has to be supplied (and removed) is much lower than the one needed during the emergency mode of operation. The congested mode of operation is irrelevant for sizing the ventilation equipment.

During maintenance work in the CBA-BT, train traffic is restricted or stopped. Maintenance works can affect the single-bore tunnel (in use during Phase One) more than the twin-bore considered for Phase

Two, as no alternative route is possible when people are working in the tube. Generally, rail tunnel doors are employed in order to separate the tunnel segments under maintenance and in order to provide controlled ventilation conditions.

Tunnel parts with maintenance operation have to be provided with a longitudinal air flow. Fresh air supply is needed to remove polluted air and to provide sufficient working conditions. The amount of fresh air that has to be supplied is much lower than the one needed during the emergency mode of operation. Thus, the maintenance mode of operation does not determine sizing of ventilation equipment.

In emergency operation, it is most important to control the propagation of smoke. While natural ventilation allows the removal of smoke only under certain boundary conditions, mechanical ventilation allows full control of the smoke dispersion. For the CBA-BT, specific ventilation requirements must be considered for Phase One (single tube) and Phase Two (double tube).

Concerning the emergency ventilation, the following principles must be adopted:

- Longitudinal flow of air/smoke in incident tunnel: The objective is to achieve the critical velocity, i.e., no back layering of smoke, which will protect escaping passengers upstream of the fire from the effects of the smoke (see Figure 4, page 32), and which provides a defined access for rescue and fire fighting services. This principle will be applied for Phase One of the CBA-BT. Longitudinal ventilation inherently implies the risk of moving smoke in the direction of

Table 2: Features of TVS for Phase One

| Element | Description |
|-------------------------------------|---|
| 1. Access tunnel | Connects to the MFS and enables the passage of people, vehicles and equipment from the outside. This is fundamental during the construction and the maintenance of the rail tunnel, as well as in case of emergency for the evacuation of passengers and the entrance of rescuers. Rescue areas in open space shall be provided at the portal of the access tunnel. |
| 2. Ventilation station | To be constructed at the portal of the access tunnel. In case of emergency and a fire-related incident, this will provide fresh air from the exterior and allow the extraction of smoke and hot air. In case of maintenance, safe working conditions will be provided by enabling air exchange and controlling the climate inside the tunnel. |
| 3. Central safety tunnel | To be connected to the access tunnel. In case of a fire-related incident in the rail tunnel, this will serve as a safe escape area for passengers. The central safety tunnel can also provide a higher safety and easier construction procedure for Phase Two. Suitable for handling an emergency situation with passenger trains having a number of individuals higher than that of freight trains. |
| 4. Cross passages in MFSs | A set of seven equidistant cross-passages is foreseen connecting the central safety tunnel to the rail tunnel. As the maximal train length is foreseen at 750m, the corresponding distance between two cross-passages is fixed to approximately 100m. Fresh air will be supplied to the cross passages. Passengers will use the cross passages to walk from the incident area in the rail tunnel to the central safety tunnel. Setting of equidistant cross passages is needed for handling incidents of passenger trains where individuals are generally spread all along the train. This is not essential for freight trains, but must be considered already during Phase One in order to prepare the construction of Phase Two. The construction of Phase Two must not affect the civil elements of Phase One. |
| 5. Cross passage doors in MFS | Cross passage doors are needed as a separation from the rail tunnel. During normal operation, these doors are closed. They may be opened in case of maintenance or emergency. |
| 6. Passing track | Constructed to allow more trains to pass the tunnel and more flexibility in both phases. Also permits more rapid evacuation of the tunnel and facilitates access to the tunnel of fire-fighting and rescue trains. |
| 7. Separating wall | In case of a fire-related incident this contributes to decreasing the effect of fire on the two tracks. This increases the safety of passengers and is important for handling fires on freight trains. It increases construction costs but limits the damages on the civil construction and prevents fire propagation from one train to another, i.e. the design fires do not need to be modified to consider multiple fires. |
| 8. Smoke extraction point and ducts | These must be provided for a fire-related incident in order to control the propagation of smoke and enable passengers' self-rescue. Extraction points and ducts shall be located above the main and the passing track in order to handle possible fire locations. Their dimensions should be designed for handling fires on freight trains as they represent the major source of traffic for both Phase One and Phase Two. Fires on freight trains could be very important and an optimal sizing of the extraction points is required. |
| 9. Manoeuvring area | Two will be provided to the central safety tunnel in order to facilitate road vehicles' change of direction. Areas of approximately 500m ² are foreseen. |
| 10. Water supply | Each MFS shall be equipped with a water supply sufficient for fire fighting. Each water reservoir of the MFS shall store about 200m ³ either inside or outside the tunnel. |
| 11. Drainage water | In case of fire, the water in the drainage system may become contaminated. This may result from the release of dangerous goods as well. In order to avoid environmental impact, the drainage water has to pass to water basins located at the portals. |
| 12. Rail tunnel doors | These are needed during maintenance operation to separate the tunnel portions under maintenance. During emergency operation rail tunnel doors shall be appropriately closed in order to counteract the natural draft effect. |
| 13. Cross passages in tunnel | Cross-passages will be considered every 500m. The construction of the cross passages will be initiated during Phase One and completed at Phase Two. |
| 14. Jet fans | Jet fans may be foreseen near the tunnel portals to support the mechanical ventilation. |





escaping passengers and rescue services. Even if the position of a fire is known exactly, this dilemma cannot be eliminated unless local smoke extraction is applied. However, operating the ventilation system in a proper manner can moderate the harmful effects of this ventilation principle, e.g., a moderate air velocity at the beginning of an incident will support the smoke stratification. The advantage of providing defined conditions outweighs the disadvantages

Below: Figure 5, MFS during Phase One (numbers refer to feature in Table 2)
Bottom: Figure 4, twin-tube tunnel with ventilation station and cross passages

of the longitudinal ventilation. Pressurisation of the escape routes: The objective is to provide a flow of air towards the incident tube when cross-passages are open (see Figure 5, below). This will be applied for Phase Two of the CBA-BT and in general for handling emergency operations in an MFS.

Phase One TVS concept

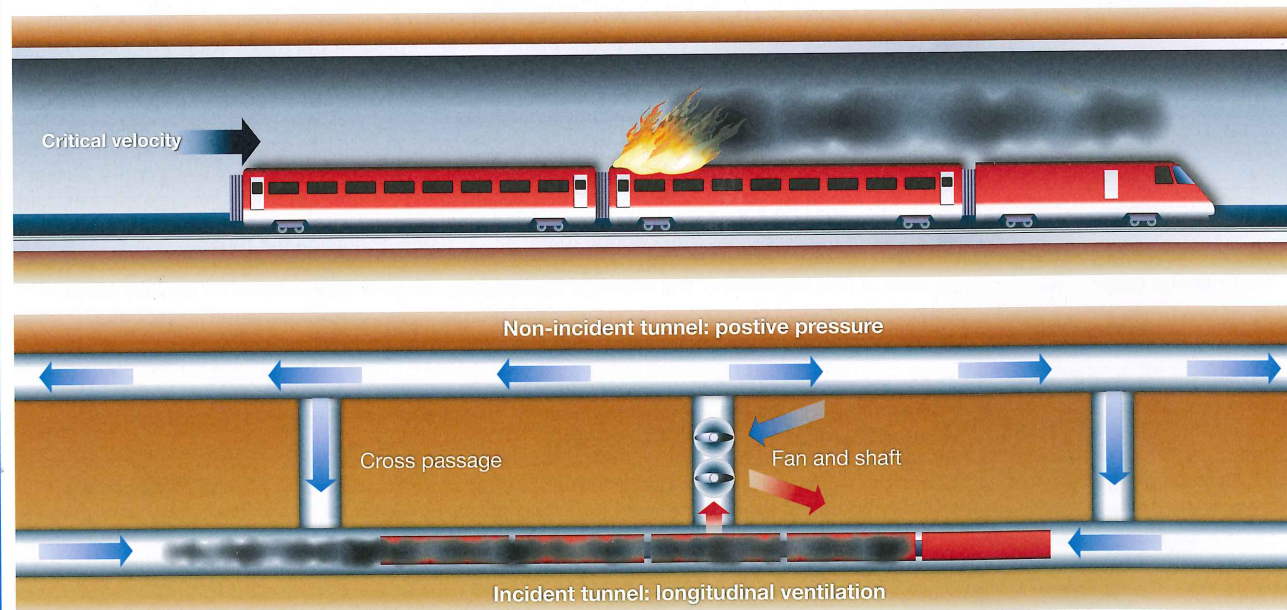
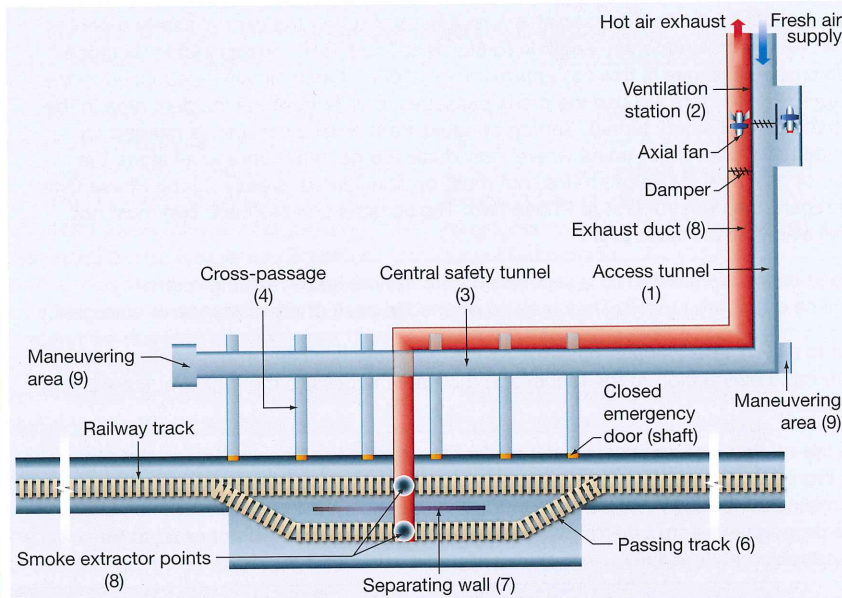
One ventilation station will be located at each portal of the access tunnels of every MFS. In order to reach 100 per cent redundancy, each consists of two fans for supply and two fans for extraction (with associated dampers). By configuring the dampers at the axial fans it is possible to

direct air via a number of paths and enabling system flexibility to provide the required level of redundancy. Possibly additional jet-fans may be installed near the tunnel portals. The main features of the MFS and of the TVS for Phase One are presented in Table 2.

In part two of this paper, to appear in the next issue of *T&T*, the basic concepts for the ventilation during the four operation modes are described.

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Jacked box and structure techniques

Box jacking in its various forms provides a safe, reliable means of excavating beneath sensitive infrastructure. James Thomson, chairman of Jacked Structures, explores the options available

The large programme of infrastructure improvements during mid to late 20th century created the need to install subways, underpasses and other underground structures without disruption to the surface or traffic flows. This led to the development of horizontal construction methods based on jacking techniques initially pioneered in the '60s and '70s.

The three main approaches that were developed and find use today are box jacking, advanced support structures and modular jacking.

Box jacking

The most basic approach, which is still widely used, is box jacking—where a prefabricated box structure is located on a launch pad, adjacent to where it is to be installed, and is then jacked into the ground with excavation taking place within an open face shield (see Figure 1, right).

Many such installations have been undertaken under highways, rail routes and runways. The underpass under Smitham Junction Station, UK, carried out by Hochtief gives some idea of the size and the large number of hydraulic rams that may be required. This structure, weighing 8,500t, at 10m high and 25m wide, required up to 14,500t of jacking force to install over a length of 37m.

Perhaps the most high profile box jacking installation was in the US for the three large underpasses jacked under operational rail tracks in Boston, as part of the 'Big Dig' project to create the new I-90/I-93 interstate interchange. The tunnel boxes were up to 24m wide, by 12m high and the longest drive was 115m. These lengths required the use of intermediate jacking stations to distribute the load. The onerous and variable ground conditions comprising soft marine deposits with old piles and buried quay walls required ground

stabilisation by freezing. As the rail tracks were for the most part at ground level, the construction of deep launch pits was a key element for construction and installation of these large tunnel boxes.

An approach used in Germany is to install temporary full support beams to carry the rail track load over the structure being installed.

One variation developed in Italy is based on installing a supporting structural grid to the rail tracks during short, overnight possessions. The box is designed to directly slide beneath the grid picking up the load as it is jacked under the tracks.

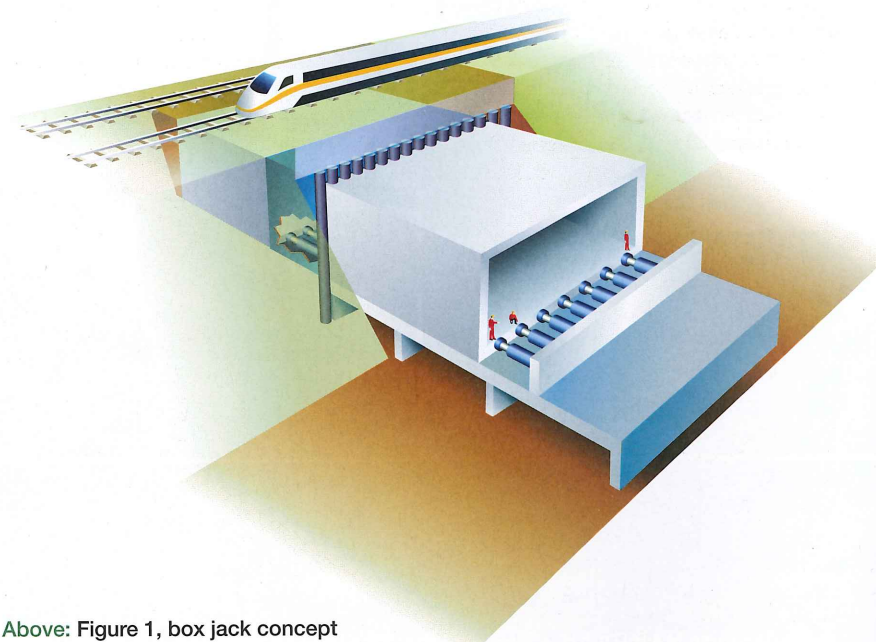
A method from France is 'Aurofoncage' which is based on constructing in-situ boxes either side of the track and, by use of tendons and hydraulic jacks, pulling the sections towards each other as excavation progresses until they meet. An in-situ junction completes the structure.

The box jacking concept is a widely used approach with projects undertaken in many parts of the world.

Advanced support structures

This technique is based on the provision of some form of canopy structure in advance of the main excavation to provide initial ground support to allow the construction of the final structure. Typical approaches are shown in Figure 2 (far right). The steel tubes, which form the canopies can be installed by pipe ramming, microtunneling or auger boring.

In the case of the Bohrtec road underpass project in Athens, Greece, the tubes were installed using pilot boring techniques. With the canopy in place excavation can progress in stages, installing framing to the tubes to provide structural support. Once excavated and supported, the final stage is the installation



Above: Figure 1, box jack concept

Right: Figure 2, options for advanced support structures. A pipe roof/arch can reduce settlement (see feature, page 44)

in-situ of the structural concrete walls and roof together with the road construction.

Modular jacking

This author, when working for Cementation (that later was taken over by Trafalgar House), in the UK in the 1970s, developed the modular method. The concept is to create a support or foundation structure such as bridge abutments using interlinked precast components, which are jacked into position horizontally. The bridge deck is installed during a very limited occupation from the surface.

This method also allows for a whole series of operations to be undertaken from within the boxes such as foundation improvement, cross strutting and finally stressing the boxes together, infilling with concrete and fixing deck slide tracks. This concept also minimises the exposed soil face at any time and requires much less site footprint and launch area, as only relatively small jacking pits are needed. A number of such jobs have been undertaken in UK. A typical installation is the Wandsworth under-bridge.

The jacked arch and jacked deck

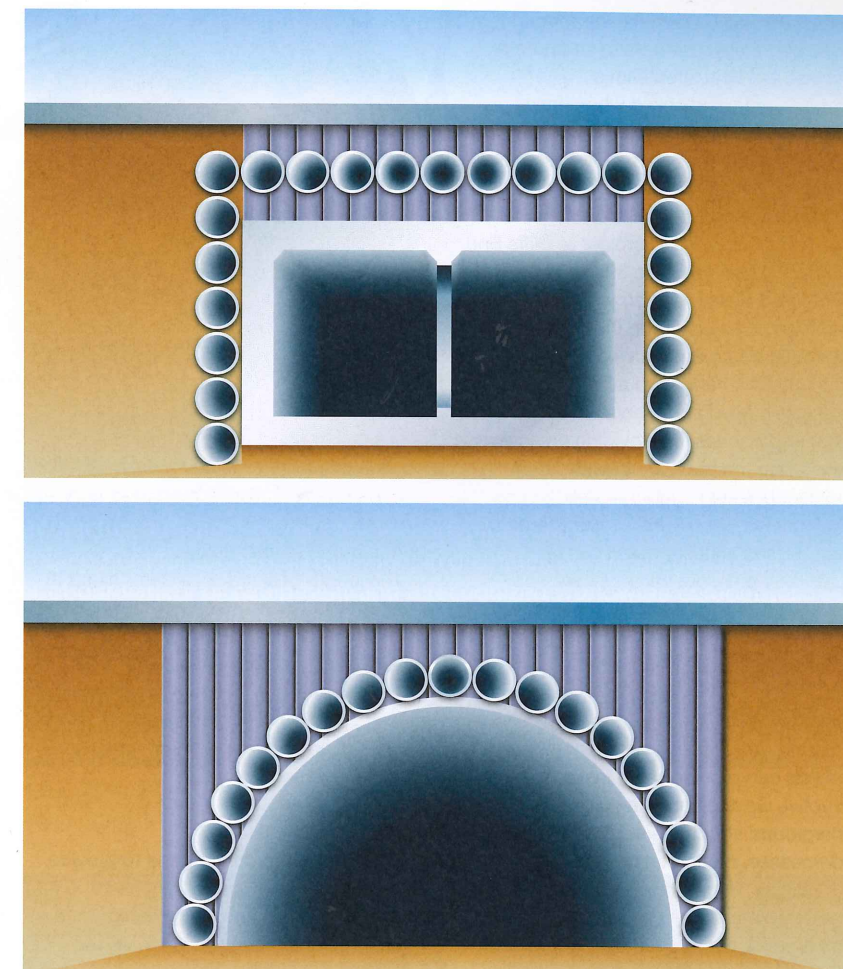
The modular system described in the previous section to install abutments and piers is a forerunner of these new patented developments. The methods are based on the concept of breaking down the installation activities into modular activities which has a number of advantages.

Both these methods are based on the provision of an access box or tunnel that allows the installation of a slide track to close accuracy along which the arch or deck units are jacked as excavation proceeds within the shield, thereby providing a full non-disruptive installation.

The jacked arch concept

This concept in its basic form comprises: **Stage 1:** Install man entry jacked foundation boxes or tunnels, which are fabricated with removable lids. These foundation units are designed to ultimately carry the permanent dead and live loading.

Right: Jacked deck installation near Cliffsend, Kent, UK by Volker Fitzpatrick Hochtief JV (see feature, page 39). Jacking from thrust blocks to the rear of the deck provided a greater stroke capacity, though interjacks were eventually deployed



Stage 2: Install a suitable slide track in the boxes to very close accuracy.

Stage 3: Precast arch sections with a compartmentalised shield fitted to the leading unit are dropped into place at the launch area and jacked in along the track with lids being removed within the shield as excavation takes place.

There are a number of variations on the basic concept.

The jacked deck concept

Another development is the jacked deck, which can also be combined with a variety of foundation configurations.

One such system is the modular system described above where the top box is modified internally to allow a slide track to be installed. These top boxes are designed with a removable section, which exposes the track as the deck is jacked into place.



The jacked deck, which can be formed from a complete cast-on-site structure or precast beams, is fitted with a compartmentalised shield where face excavation takes place.

This concept was used for the recent installation of the 126m long x 20m clear span underpass under rail tracks on the East Kent Access Road project at Cliffs End in Kent (see feature, page 39).

The initial design and construct submission was based on the construction of modular abutments but was subsequently changed to a bored tunnel access with piled abutments.

The approaches for providing an access for installing the track are based on the modular abutments and a jacked access box. Figure 3 (below) shows the alternative of a tunnelled access, which can be installed by pressure balance methods where soil conditions are unstable. The jacked box or the tunnel provides access for installing the piled abutments.

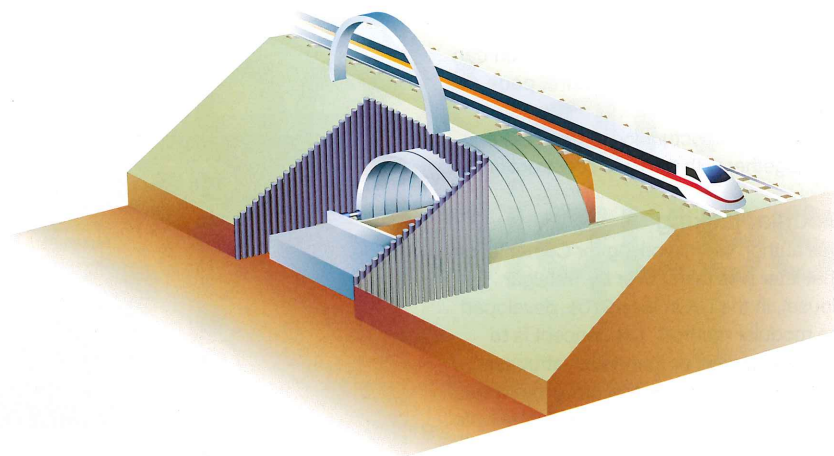
Applications

The application of jacked arch and deck methods can provide safer, faster and less disruptive ways of installing large underground structures such as underpasses, metro stations, launch boxes and parking. The methodology has considerable benefits in alluvial soils, compared to current methods, as it provides a full structural lining at all stages.

These methods and alternatives are equally applicable to where any large underground structure needs to be installed with minimal disruption.

Underground metro stations

Both the jacked arch and jacked deck technologies have a capability of installing



Above: Figure 4, the jacked arch concept is a modular jacking method

underground station boxes.

The length of a station is determined by platform length required to accommodate the number of carriages. Current requirements for spans and lengths for stations can easily be accommodated and longer lengths would be possible. A variety of layouts are available to accommodate most requirements.

Launch boxes

Launch boxes are constructed to provide an underground structure from which TBMs can be built and launched to construct the running tunnels. They then provide the basic structure within which the permanent station is constructed.

Typically these will be 22 to 24m span and around 200m long. The height will be determined by the diameter of tunnel to be driven but for a twin track tunnel this could be six to 7m diameter so internal depth of box could be up to eight or even 10m. These would be driven from a central access shaft in both directions using the jacked deck method to give the clear spans required for the project.

Advantages

Specific advantages of the jacked arch and jacked deck include:

- Continuous support of the excavation with a full structural lining while excavation proceeds, eliminating the possibility of collapse
- The risk of injury or death to workers is virtually eliminated
- Any surface settlement is minimal and adjacent buildings, property and the public are protected

Left: Figure 3, access tunnel with piling for abutments and provision of slide path. Accuracy is vital for the bearings

- The methods are applicable to construct both shallow and deep structures
- Jacked arch and jacked deck structures can provide greater clear spans over much longer drive lengths than can be achieved by jacking boxes.
- Jacking precast elements to form the structure can be undertaken from a small launch pit excavation
- The launch pit requirement is reduced
- Modular units can be precast and brought to site. The quality and accuracy can be of a higher quality with factory production techniques
- The jacking loads are greatly reduced and this in turn means less jacks and reaction provision
- The accuracy of both the line and the level of the finished structure can be a few centimeters

Final comments

Although the jacking concept appears simple, the work is undertaken in high-risk operations when working below operational rail tracks and highways requiring high levels of supervision throughout.

Unlike most civil works you only get one opportunity to get it right, and the concept, detailed design development and installation procedures need to be developed and controlled meticulously. There are many key areas, among them: geotechnical including pre-treatment; shield design; excavation procedures, settlement control; close dimensional accuracy and high quality of structures.

Anti-drag systems to reduce friction and prevent the migration of soil particles are also vital, as is the provision of sufficient jacking load, as well as its application to the structure being jacked.

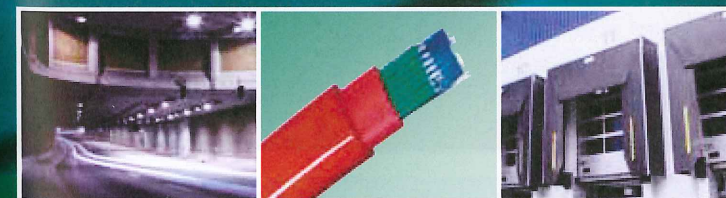
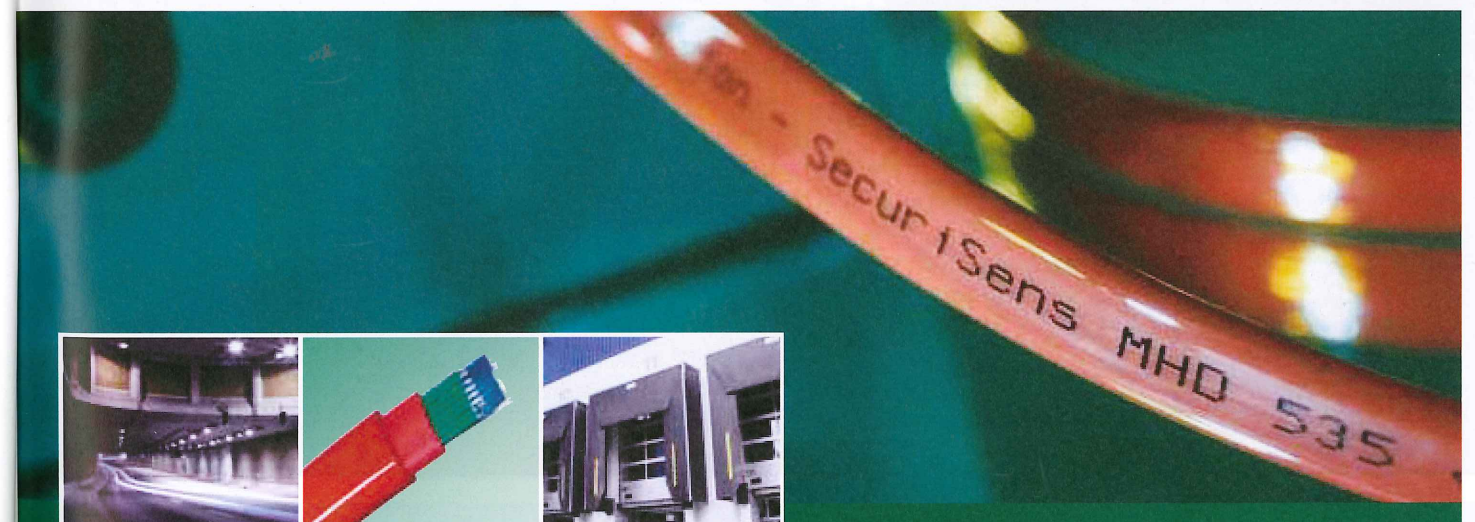
Finally, restraint structures for the jacking loads must be provisioned. ■



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World's longest structure jack



The world's longest jacked structure forms a highway underpass beneath a road-rail crossing that sits on unreliable Thanet Sands. Alex Conacher reports from site

The Cliffsend Underpass in Kent, UK, is the world's longest jacked structure at 126m. A deck with a single clear span of 20m is mounted on a precision slide track built in cramped tunnels, the piling of which was a difficult project on its own.

Project overview and timeline

The underpass project is part of the East Kent Access Phase Two highway project in Kent. "This forms the final link from the Thanet Way (A299) highway on the north Kent coastline from the end of the M2,"

says Mark Pritchard, design manager for the VolkerFitzpatrick Hochtief contracting JV (see Figure 1, page 40). "Which then turns into the A2 going down to the Dover area. This is the last 'wrap around bit' on the eastern coast. So it's a strategic link for Kent," adds Pritchard.

Kent County Council (KCC) awarded the contract for works to the JV with a scheduled start date of October 2009. Although the project value is listed as GBP 65M (USD 103.1M), Pritchard says that it was part of a GBP 87M contract from KCC that covered other aspects such as land

Above: The jacked deck units were moved by a 'skid system' that was developed by Mammoet de Boer

acquisition and an interface between KCC and Network Rail.

The underpass accounts for a third of the value of the GBP 65M project and is the focus of these works.

The contract end date is September 2012, though it is expected that March will mark the end of work on site. Also involved is construction of 9km of new dual carriageway and a road bridge over rail.



Left: Cliffsend in the Ramsgate area of east Kent
Below right: The jacked structure with shield. It is the world's longest at 126m

and you would go square, and also not 6m below the tracks. We had to reposition a pumped foul sewer at that level by lifting it up to a higher point—fortunately the pumping chamber here could be made shallower by 1.5m.

“But the main concern was digging the two 12x8m holes with the fill on top and maintaining face and track stability. That was the fundamental problem of the entire job: how to install this massive structure without impacting rail, especially as rail services would not be halted or even slowed for us. Jacked Structures and Atkins came up with an alternative for us that incorporated Jacked Structures’ jacked deck.”

The deck

The jacked deck is a concept developed by James Thomson, CEO of Jacked Structures. Thomson tells *T&T* that experience and burned fingers led to the belief that improvements could be made to standard box jacking (see feature, page 34). Thomson explains that the original idea they presented was to create a slide track inside jacked boxes at the side, and then jack in a single-span deck, with a cutting shield at the front, to form the roof of the structure.

The track would be set in the top jacked box at each side of the deck running the entire length of the underpass.

Thomson adds, “Friction is the absolute concern with jacking. Jacking a deck rather than two boxes means that all of the friction we must deal with comes from the ground above, and a bit to the sides, and quite an amount from the base as well—as when you are jacking a complete box—and also, there is a chance of two boxes interfacing and causing friction. That is very dangerous. The jacking load needed to get the deck in is also of course much lower than a full box.”

Pritchard adds that the 3 to 3.5m face of the deck is much less to manage than a 12m face. He continues, “It is much wider than two boxes, but it is divided into manageable segments by the shield at the front. And the vision was for it to sit in the boxes, which are still big, the size of a room, but manageable. They are concreted together and a slide track installed on top. So you have the walls, the roof and you excavate out the rest.

“We didn’t go with the box sides in the

end, we went with 3m tunnels as it is a more known technology. Before we got the contract, we spoke with Network Rail to explain the benefits of the deck. We summed this up as: reduced face height, foundations in place so it isn’t going up or down and the already huge resistance, which would result in a phenomenal force on the bottom of a box, making the required jacking forces astonishing. The design, which included workshops with Atkins, Jacked Structures and Mammoet de Boer, took a total of 18 months from October 2009 through to the final installation.”

Jacking

Jacking 2,500t deck sections is not the smallest of challenges that can emerge from a project like Cliffsend. The specialist jacking subcontractor, Mammoet, developed a skidding system to move the sections into position in front of the thrust blocks, which are equipped with ground anchors by Keller. Ordinarily you would push against the ground behind the unit; this was not possible as a large area has been cleared to get the units in. “The skidding system lifts the cured unit up 50mm off the ground and moves it with a kind of cam system that puts pins in as it

goes,” says Pritchard. “Relatively speaking it is not a huge weight, considering the 10,000t fill weight. The legs of the unit slide through a gap in each thrust block.

“The jacks on each block can provide a 7,000t jacking capacity and there are intermediate jacking stations between units one and two, two and three and three and four. These have another 7,000t capability giving a total 35,000t of jacking force. Interjacks were between all units except the last two. You push from the back for as far as you can, then you deploy the interjacks and jack one block off the next.

“The interjacks had a stroke capacity of

120mm, so we moved forward in increments of 100mm. A bigger stroke of 300 or 400mm is possible from the back. The steel edge of the shield cuts into the face so there is never a void at the front. At points the chalk was too hard so we had to dig up the front with the agreement of Atkins and Network Rail but the perimeter, the sides and the top did the final cut. We never cut above or to the sides so as to minimise overbreak.

“All of these solutions have been used before, but I don’t think they have ever all been used together.”

Tunnels and slide deck

The tunnels housing the 128m-long slide tracks were not specially designed in any way. The drives were executed by Murphy with EPBMs. Abutment walls were piled down from the tunnels. Four 50mm diameter piles of segmental rebar were sunk 14m down through each segment. Some 530 piles were completed in three months with a Keller-operated Clem 702 piling rig (and segmental augers) that, Pritchard says, had virtually 0mm clearance in the 3m diameter tunnels. “If I were doing this again,” Pritchard says, “I would bore the tunnels with an extra 0.5m diameter, just to save the pain of working in such a constricted environment, it is definitely worth the initial investment for when you get to the piling stage.

“The tunnels would be fully grouted as any permanent tunnel, and following the drilled holes and piles through the bottom, and the installation of the track, the top bit is cut off with peckers and drillers as the jacked deck advances.

“Threaded bolts support the slide track to a 0.5mm tolerance. The 60mm conventional bridge bearings we used were put to the limit. If you didn’t have the 0.5mm tolerance on the alignment of casting beam... well, it would be almost impossible to replace one. The bearings were tested to double load. Some showed signs of distress by the end of the jack, probably due to the guidance system pushing against the chalk at the side. In the open air the deck was moving all over the place; it moved 50mm to the side at one point. The bearings showing the most distress had a bit of sideways movement, but all were intact at the end. Some look like they are almost going to delaminate.”

Steel ropes and sheets

Thomson’s view that time spent on the concept pays dividends later is echoed by Pritchard on the issue that both tunnellers gave as the primary concern: friction.



Underpass situation

The village of Cliffsend hugs Pegwell Bay some 2km southwest of Ramsgate in Kent, UK, and is bisected by the Ramsgate to Ashford main railway line. A level crossing divides Foads Lane to the south of the line with Foads Hill to the north. The Cliffsend underpass was driven directly under this point where road meets rail. “Because of the geometry and topography of the site,” says Pritchard, “we had to drive the underpass through at a very acute angle to the crossing. Normally when going under existing rail, you would go square to the track to minimise distance. Here you can’t, so the zone stretches about 100m-long, though 25m wide.

“To make matters worse, although we generally had very competent chalk to work with, there was one band of Thanet Sands to deal with. And of course it passed directly below the worst point—the level crossing. [...] ‘Brilliant’ was the initial thought, how on Earth could we prevent the railway from settling?”

Jacked deck solution

Jacobs was the internal designer for KCC and they worked with BAM Nuttal. An outline design was put to Network Rail, though the underpass tender was put out as a contractor design item. Jacobs’ solution was the indicative, but not the detailed final design. “We had jacked box experience prior to this job,” says Pritchard. “So we got on the tender list and engaged both Atkins and Jacked Structures for their particular expertise. We got them to come up with a solution to satisfy KCC, and more importantly Network Rail.

“The design we inherited was an old solution. Two 12x8m boxes jacked in side by side about 6m below the railway. They would probably be staggered so they can be done simultaneously. There were big concerns hanging over this indicative solution. Normally jacked boxes aren’t as long as this (final length 126m) structure

Pritchard says, "The anti-drag system looked exactly like the concept; it was precise. Basically with jacking a box or other structure, there is a risk of micro lateral movement of the soil at the interface between the deck and the overlying soil due to frictional forces leading to settlement and heave. To overcome this issue, you need to employ an anti-drag system."

"The most common form is a steel rope system. You anchor the ropes at one end, in our case the western wall head, and 19mm-diameter ropes lie all across the deck in two-diameter centres, so half the concrete is covered. Lubrication is easily pumped in and so friction is reduced. The problem we encountered was the sheer lengths of rope needed. Usually boxes are 30-50m long and we are more than twice that. There was no room to store the required rope on the drum, you just couldn't do it."

Thomson came up with the drag sheet solution at Cementation Trafalgar. The sheets predate the ropes and served the Cliffsend situation well as they were thinner. A grade 550 steel was used. The design

called for a 4mm thickness but this can't be rolled very well, so two lots of 2mm steel were used. The force was seen as the limiting factor as the sheets could break. Corus-made sheets were bolted to the soffit with a standard grease pumped in. There was a backup system of bentonite delivered through a pipe network between the sheets but it was not needed.

Rail concerns

Network Rail's position on the project was that there would be no interruption to regular services at all. This meant there could be no possessions. A 60mph (97kph) speed limit was imposed, but Network Rail was uncomfortable with this and a tighter 40mph (64kph) was imposed, though over a smaller section of the route so train times were not noticeably affected. The JV said its position was that although it was contracted by KCC, this was a Network Rail job and managing that side was the difficult concern of the job.

The road was shut to cars during works



Above: The foot of the jacked deck rested on a slide track. As the structure advances, the crown and side of the tunnel is broken out to reveal the track; **Below left:** Visible section of tunnel, deck foot and slide track as T&T visits

and was due to reopen a few days after T&T visited the site.

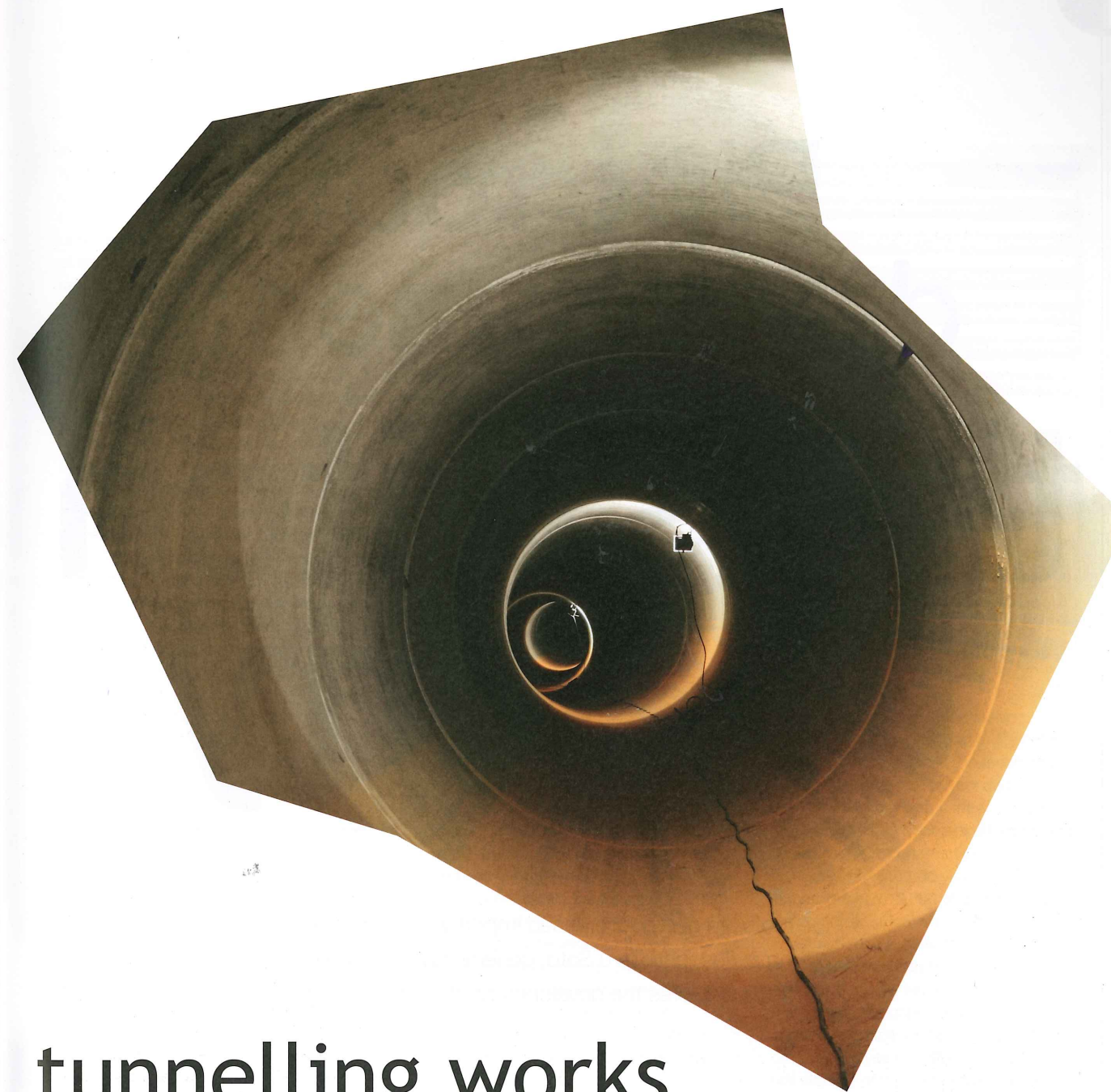
On the concept

Thomson concludes, "A recent T&T poll showed that nearly one in three tunnellers believe that the use of NATM in soft ground is fundamentally unsafe. I share this view. NATM and SCL have been widely promoted for use in soft ground even in high-risk situations despite some notable failures and problems." Thomson continues, "The main things that stand out with the jacked deck method, as far as I am concerned, are that it is broken down into a number of units so there is always a structural lining where we are working. Nothing will ever collapse and fall on the workers or cause a major settlement."

"You could theoretically have a slip at the face but you can control that. At worst some amount of material may be lost, but not huge amounts and it certainly wouldn't be a disaster. This is in summary a very safe method of doing a difficult job: putting a large structure under an existing facility."

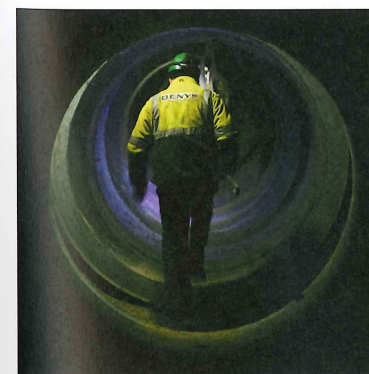
"If you are going under a railway, or maybe creating underground structures under somewhere like Oxford Street or Regent Street, safety must be the primary consideration. You can't afford to make any mistakes or you will have an even greater disaster on your hands."

"The issue in part is that people just don't yet realise the potential of what we can do with this technology. The jacked deck concept opens up the potential to install without surface disruption even longer and wider spans than those achieved at Cliffsend."



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In 2030, it is expected that 60% of the world population will live in cities, which translates into five billion people needing modern mobility and utilities infrastructures. In the densely populated settings resulting from this population explosion, it will be no easy task to develop the necessary infrastructure or, indeed, maintain it. Working underground will often be the only possibility and this will take place through a complex network of tunnels, sewers and shafts without disturbing above-ground activities. Fortunately for Denys, this is the company's primary field of expertise.

Photographs / In Flanders, Denys is contributing to the modernisation and expansion of the sewer network in various locations. Here, sewers are constructed using advanced (remote-controlled) drilling techniques.

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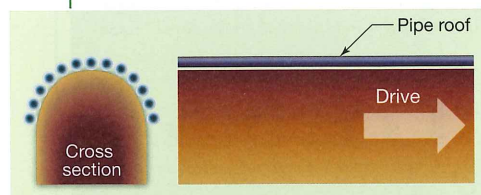
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Pipe roof development: the switch to slurry

Pipe roofs are gaining increased importance in Japanese jacking philosophy. Toru Sato, general manager at Iseki Polytech, explores the development of the technology

The pipe roof method has increasingly been used as a supplementary method of tunnel excavation during the recent period of rapid economic growth in Japan. The pipe roof method has developed and has been adapted from opened face shield tunnelling and auger boring. Recently, the viable range for pipe roof construction by

Below: Figure 1, Schematic view of the pipe roof method



slurry pipe jacking has expanded, up to one case of a 150m-long jacking. Because of the rigid behaviour of the lining, the results show little subsidence, making this a highly reliable process for tunnel construction.

The use of underground space directly beneath buildings, highways and railways has become a focus due to the recent emphasis on effective use of underground space, as well as the elimination of regulations relating to underground use. Therefore the pipe roof method has been attracting the attention of engineers as a supplementary construction method. In particular, since slurry shield pipe jacking has been used with the pipe roof method, use of the method has increased sharply.

This method uses mud slurry that is formed around the pipes in order to stabilise the surrounding soil. In the pipe

roof method, tubing elements constructed by slurry pipe jacking are near each other longitudinally. They are installed around the tunnel exactly, and create a rigid and stable lining before the excavation of the main tunnel. Thus, the aim of using slurry pipe jacking with the pipe roof method is to extend tunnelling operation into urban areas in the most demanding conditions, such as non-cohesive soils, working in the presence of ground water, limitations in surface settlement and also different depths of overburden.

Technology development

Pipe roofs are constructed along with the shapes of the main tunnel prior to the tunnel excavation. Figure 1, left, shows a schematic view of a pipe roof.

Generally, methods of pipe roof

construction can be classified into four types: horizontal boring, auger boring, cutting edge and also slurry pipe jacking. Horizontal boring is viable for variable soil conditions, with a rotating cutter bit in front of steel pipe. A horizontal bore within the range of 80 to 300mm in diameter is typically used in Japan.

The first horizontally bored pipe roof was constructed for the Atami Tunnel, a Bullet Train (Shinkansen) tunnel project in the 1960s. A congested urban environment of hotels and roads meant that ground subsidence had to be avoided. A set of 30m-long, 84mm-diameter steel pipes formed the earth retaining wall. These steel pipes, and steel supports successfully prevented any subsidence from excavation.

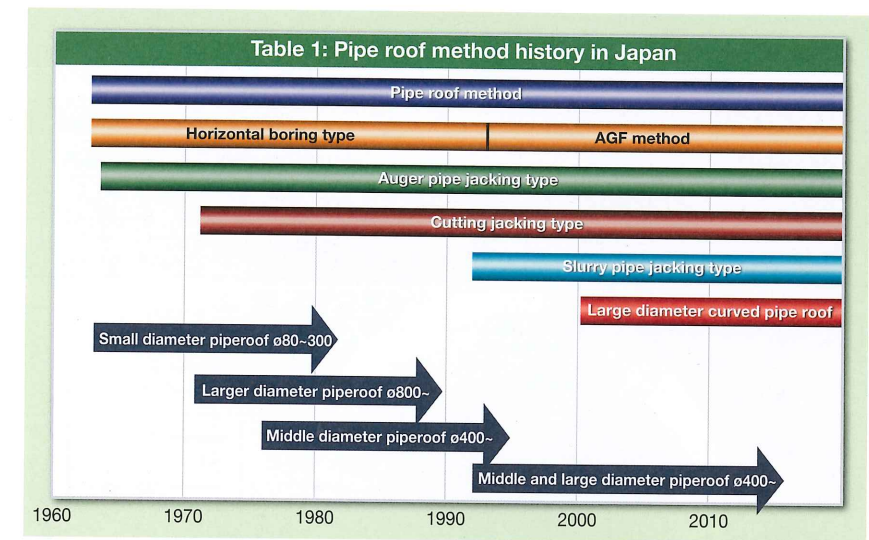
In 1963, the first use of the pipe roof method by auger pipe jacking was undertaken to construct a pedestrian underpass. It was used as an auxiliary procedure; pre-bored steel pipes with interlinked steel sections were jacked. In the early 1970s, the diameter of the pipes began to increase as the system became more popular and was adopted for larger tunnels. The auger method and cutting edge method were the leading systems in the early projects.

The pipe roof method is one of the best ways to protect surrounding ground or existing infrastructure. One problem that emerged was the difficulty to maintain the proper deviation and alignment on long distance drives. However, this kind of problem could be overcome following the later adoption of slurry jacking.

The first pipe roof executed by slurry pipe jacking was in Japan in 1993. This was some 30 years after the first (horizontal bore) pipe roof. This pipe roof construction was formed of 812mm o.d. steel pipes at 130m long. The project was for construction of a railway station under a live railway and congested road. Under these conditions, a long distance pipe roof was requested as temporary works. It had to cut through a layer of mixed soil and required highly accurate pipe jacking to keep in alignment over the long distance.

Slurry pipe jacking is the preferred method if water is expected as there is no need for grouting or injection as there is with auger boring, for example.

A siphon culvert was carried out with slurry pipe roof construction under the Karasawa River in Japan in 1995. The geology was made of a gravel and cobble layer with a high water volume. Under such severe conditions, the auger or cutting edge methods would call for chemical grout injections to the excavation face area



Above: Table 1, a history of pipe roof construction in Japan

to stabilise the ground. In addition, efficiency would be uncertain and unreliable. Therefore, the slurry method is the most accurate and safe method among them.

Generally speaking, an arrival shaft is necessary for slurry pipe jacking. These are becoming difficult to build in increasingly congested city areas and auger pipe jacking has been substituted in. However, new slurry machines have been developed for pipe roof construction, which can be pulled back to the jacking shaft through the pipe upon completion, mitigating the need for an arrival shaft.

Following the development of a retrievable slurry machine, pipe roof use has expanded in Japan and long distance pipe roofs have become popular in underpass construction. Table 1 (above) gives a chronological history of the pipe roof method in Japan.

Improving accuracy

Horizontal boring has no steering method and therefore tolerance cannot be guaranteed. Generally, this method has a tolerance of approximately 1/200 of driven length (Ishibashi et al, 1997).

Auger boring incorporates augers that remove the soil from the face and are not suitable for wet soil conditions below the water table. Drive lengths are restricted to about 50m because the driving device is located in the launching shaft. Typically, an auger method within the range of 300 to 600mm in diameter is used in Japan. It is difficult to ensure the accuracy in particular soils such as gravel or cobble layers, and the auger machine only has a simple steering device. Therefore specific tolerances cannot be guaranteed. Generally, this method gives a tolerance of

approximately 1/300 of driven length (Ishibashi et al, 1997).

With the slurry type pipe jacking method, a range of 300 to 1,200mm in diameter is typically used in Japan. The machines are equipped for remote control and steering, and are operated by a central management system to ensure the required safety and accuracy in the construction work.

Generally, this method yields a tolerance of approximately 1/2,000 of driven length.

Table 2 (page 46) shows tolerance of construction. It is clear that slurry pipe jacking is superior to the other methods.

If the pipes are set with greater accuracies, the gaps between each constructed pipeline can be narrower. In order to analyse the effects on surrounding soil stability of the gap between each constructed pipeline, numerical analysis is used. In the trial, a 50m wide horseshoe shaped tunnel was modelled. The tunnel had an overburden of 6.5m and a height of 50m. The pipe roof was installed and consisted of a single row of jacked steel pipes. The pipe roof row was formed in an arch shape.

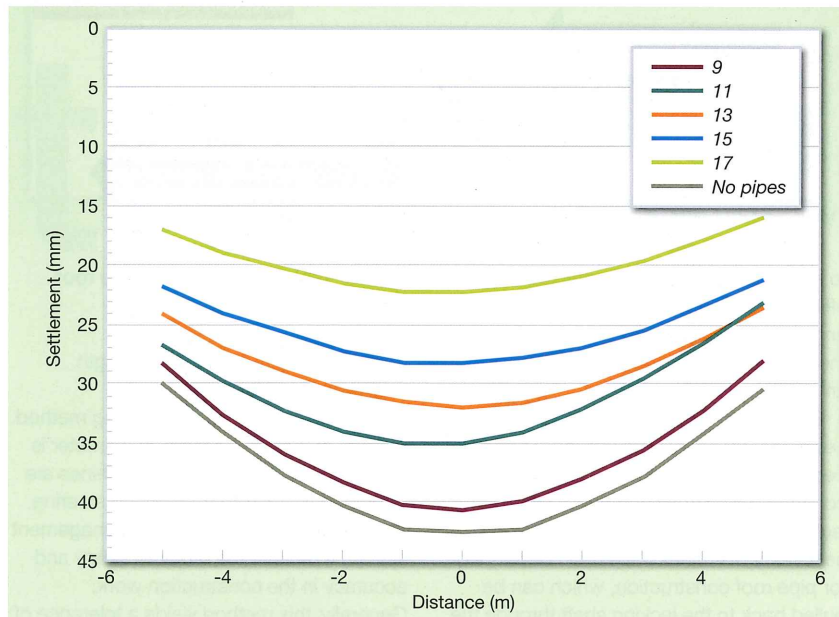
In the numerical models, the following assumptions were used:

- 1) two-dimensional plane-strain problem
- 2) the failure criterion of Mohr-Coulomb was selected
- 3) all the materials used in modelling were assumed to be the plastic material.

In the first stage of analysis the gap between each pipe of the roof and its effect on ground surface settlement was considered. This analysis was carried out

Table 2: Tolerance of construction

| Boring method | Tolerance of construction against driven length | Tolerance of construction with example length of 60m |
|---------------|---|--|
| Horizontal | 1/200 | Approximately 0.3m |
| Auger | 1/300 | Approximately 0.2m |
| Slurry | 1/2,000 | Approximately 0.03m |

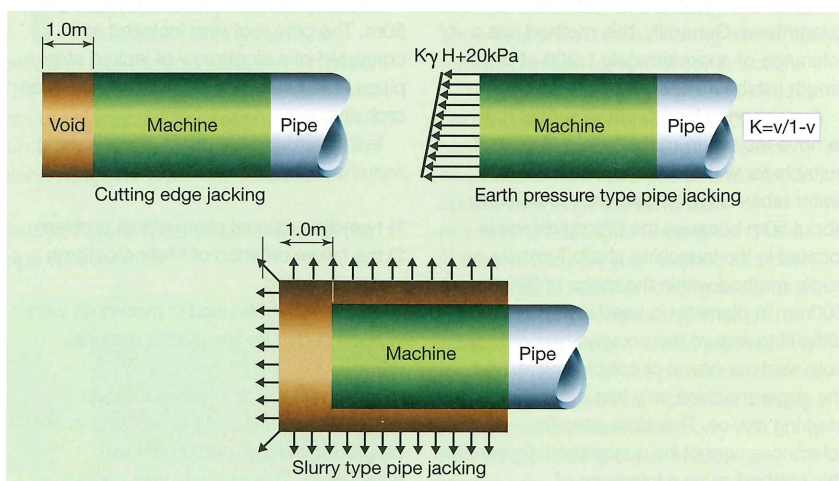


Above: Figure 2, steps of the first analysis; Below: Figure 3, numerical models were developed for different jacking methods

with a gap set at a distance of 0.6m, 0.4m, 0.25m and 0.1m. Figure 2 (above) shows the steps of the analyses in this case. The gap between the pipe roofs and the tunnel crown in this step was 0.5m. The results show that the concentration of stress

around the pipes reduces when the gap narrows. Surface settlement graphs showed an increase in settlement when the gap between each pipe roof widened. When the density of the pipe roofs around the tunnel crown is higher, stress distribution in the surrounding soil is better than when at a low density.

In the second stage of analysis, the gap between the pipe roof and the tunnel crown was examined. To vary the distance



between the pipes and the tunnel crown, the pipe roof arch diameter was increased. The number of pipes in the arch remained fixed at 15, therefore as the arch diameter increased, the distance between the pipe roof and the tunnel crown increased, and the gap between each pipe increased (Shimada, Sato, Sasaoka, Matsui, 2010). The results show that an increased distance between the tunnel crown and the pipe roof leads to a greater settlement. A distance of 0.5m creates a settlement 1.4 times greater than a 0.1m gap.

The accuracy of pipe roof construction has a large impact on the stability of surrounding soil.

Soil stability

To compare the effects on soil stability of each jacking method, a three-dimensional numerical analysis was implemented.

For the cutting edge jacking method, the extremity of the cutting face is open. This allows direct access to the cutting face for manual excavation. Therefore, it is supposed that this method has an unsupported space of 1m in front of the cutting face for the analysis model. An EPB pipe jacking machine is a closed-face TBM. The excavated soil and material is transported from the machine chamber by a screw auger or screw conveyor. Pressure in the machine chamber is controlled by the rate of passage of excavated material through the balanced screw auger or valves on the screw conveyor. Therefore the analysis modelling of the earth pressure pipe jacking method considered that only extremity of machine has a pressure. In this study, its pressure was set at an earth pressure plus 20kPa for cutting face pressure.

The slurry pipe jacking machine is also a closed-face TBM. The excavated material is transported from the face suspended in slurry. Slurry pressure and forward thrust maintain the stability in the face.

Therefore the analytical model of slurry pipe jacking is assumed that a space of 1m in front of a machine and the circumference of the machine have a pressure. Its pressure was set at an earth pressure plus 20kPa. The earth pressure adopted for the model is set at the centre of the machine (Sasaoka, 2003).

Results show the largest settlement is caused by the cutting edge jacking method, the only open face method modelled. Second is EPB pipe jacking, and the smallest settlement is with slurry pipe jacking. It is considered that EPB has no pressure on the tail end of a machine, while the slurry machine is pressurised on all

faces. The results show that slurry pipe jacking can prevent settlement by pressurising the cutting face and tail skin.

Tohoku Shinkansen pipe roof

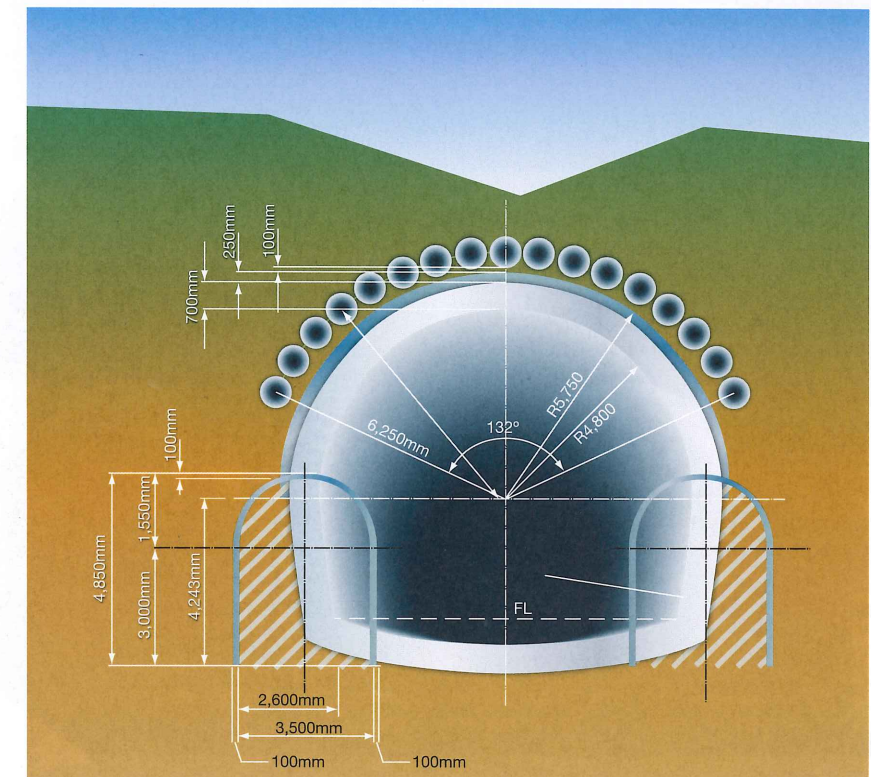
The pipe roof method has a strong track record in Japan. In the Ichikawa tunnel on the Tohoku Shinkansen Line, it was necessary for the contractor to execute the supporting construction of a pipe roof to protect a highway from tunnel works. The earth cover was approximately 3m. The shallow earth cover meant a pipe roof was the preferred support method. Slurry pipe jacking was chosen because the 91m distance to cross the highway was too great for other jacking methods (Iigima et al, 2006). The pipe roof was installed and consisted of a single row of steel pipes jacked at 0.9m spacing in the crown of the tunnel top heading.

The roof was an arch shape. The outer diameter of the installed pipe was 0.8m. The distance between the pipe roof and the tunnel crown was 0.1m. Distance between the pipes was 0.1m. The number of the pipes was 17.

Due to the highway, careful work was demanded. Pipe roof works took about four months. Though the earth cover was 3m, the effect of the pipe roof meant the tunnel was able to be excavated with stability. The work was completed laying a new tunnel without damage to highway safety. The surface settlement of the highway after excavation was about 30 - 50mm.

Pipe roofing progress

As said previously, slurry pipe jacked roofs have been around in Japan for some years. In recent years long-distance pipe roof underpasses have been carried out. There is an increasing requirement for construction work to have no influence on surface traffic near heavily congested

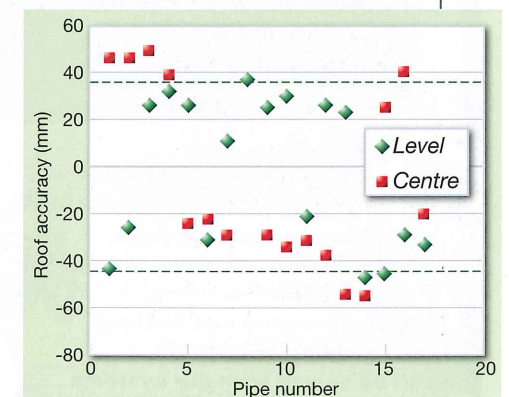


Above: Figure 4, cross section of tunnel and pipe roof
Below: Figure 5, slurry pipe roof execution accuracy

Above: Figure 4, cross section of tunnel and pipe roof
Below: Figure 5, slurry pipe roof execution accuracy

stability of surrounding soil. It was clear that the importance of accuracy in pipe setting and selection of pipe jacking method for pipe roof jacking is an important factor for effective ground stabilisation. Slurry pipe roof jacking was superior in the maintenance of ground stability. It also allows for various underground constructions.

Currently, there are many examples of this pipe jacking method in the world's urbanised areas. It is expected that this technology will grow in popularity around the world in coming years.



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The Reliable Tunneling Partner

Forward thrust

The team behind the Herrenknecht direct pipe method takes a look at the achievements of the system since its launch some four years ago



Above: The team celebrates a successful breakthrough in Florida

In the past, numerous methods and devices have been developed for the trenchless laying of pipelines in the ground to enable sensitive areas on the surface to be crossed. Geological considerations, time and cost budgets are the crucial factors determining the choice of the most suitable laying technique. Underground pipeline laying poses many

problems, such as how to work in a space-restricted area or circumvent possible obstacles both rapidly and cost-effectively.

The direct pipe method combines the advantages of the established laying methods of microtunnelling and horizontal directional drilling (HDD), thereby opening up potential new applications. One single, continuous working operation is sufficient

for the trenchless laying of a pre-fabricated pipeline and the simultaneous creation of the necessary bore hole.

As with pipe jacking, earth excavation is undertaken by a microtunnelling machine. The machine is navigable and uses a

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flushing circuit to transport the excavated material to the surface. Modern and proven controlled pipe jacking techniques ensure accurate measurement of the current position along the intended route. The force required to feed the pipeline forward is exerted by a new type of feed device, the pipe thruster. The pressure necessary for the boring process is transferred along the pipeline to the cutterhead.

The pipe thruster was developed as an auxiliary tool for the pullback of the pipe in the HDD method. It was presented for the first time at the Hannover Fair in spring 2006. It embraces the prefabricated and laid out pipeline and pushes it into the ground at thrusts of 5m.

The requisite bore hole is excavated by a slurry microtunnelling machine, which is arranged at the front of the pipeline. In terms of its general function, the machine is very similar to a conventional microtunnelling machine, one difference however being its length. To ensure the requisite curve motion of the machine and subsequent pipeline in culverts, it features two to three back-up pipes. All of the individual back-up pipe connections feature articulated tensile couplings for optimum control of the machine. Another advantage is that in an emergency, the machine and pipeline can be extracted along with the pipe thruster.

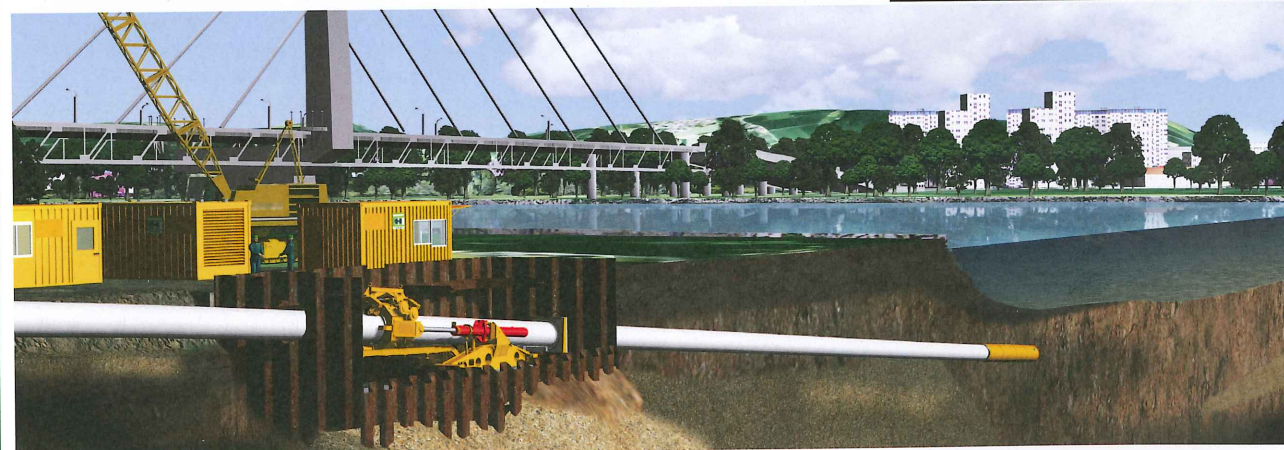
Just like the microtunnelling method, prior to launching, the machine is

thruster can be used for pipelines up to an outside diameter of 60in (1,524mm). The forces to be anchored depend on the pipeline access angle and the maximum thrust or retraction force to be applied. Horizontal forces applied can be absorbed by lateral support profiles mounted in the shaft while deep sheet pile or bore pile walls can be used for the vertical forces.

In the course of the direct pipe development process outlined below, the individual process components have been permanently improved and adapted to changing demands. For example, a launch rail is to be used in setting up the machine in the launch pit. It should be possible to save two to three days during setup using this hydraulic height- and angle-adjustable support.

The pilot project

With the aid of a HK500PT pipe thruster and an AVN1000 direct pipe boring machine, it was possible to successfully install a 464m steel pipeline under the Rhine in 2007. The steel pipe was intended to serve as a protective pipe for a water line and various protective cable pipes at a later stage. As the lack of space prevented the 48in (1,219mm) o.d. pipe from being installed in one piece, it was laid in sections of approximately 90m. The fact that the pipeline was pushed with only 80t into the small target pit in Worms Port, Germany,

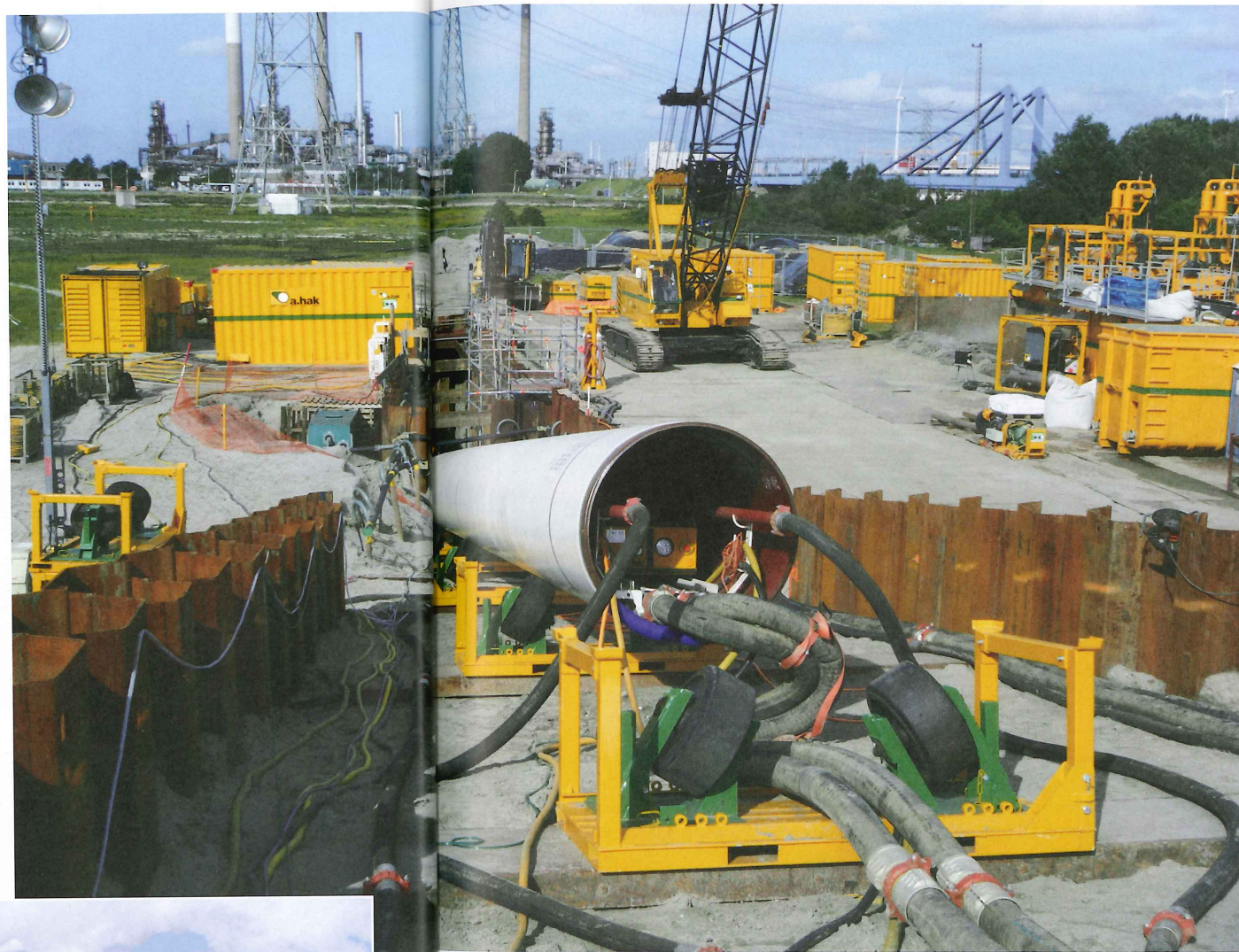


positioned at the required access angle on a launch rail in front of the launch seal, which protects against ingress of groundwater and soil. The pipeline is mounted on rollers behind the launch pit and welded with the conical section of the machine at the rear.

The clamping unit of the pipe thruster embraces the pipeline and thrusts it into the ground along with the machine. The pipe

within 13 days shows that the friction arising during the direct pipe method is very low despite there being no lubrication applied along the entire length of the pipeline. This advantage has since been displayed in the form of relatively low thrust forces required within the framework of various other projects.

As the Worms project involved a bare, uncoated steel pipe, it remained to be seen



when full clamping force is applied by the clamping unit and maximum thrust by the two large hydraulic cylinders.

Ems-outfall project

The next step in the development of the method was to install a 280m brine outlet pipeline for the construction of the Jemgum natural gas storage facility at the Rysumer Nacken near Emden. A PE-coated 48in steel pipe, in which a DN900 fibreglass pipe was subsequently inserted, was installed for a German energy supplier.

During project planning, the direct trenchless advance of fibreglass pipes in the partially soft tidal flats of the Ems estuary was not regarded as possible. A casing pipe could not be laid out in the water on account of the currents prevailing, the setup required that advance was made from land. However, owing to the tight spatial conditions, the pipe could only be installed in sections of 36m, which would

have posed a risk of the bore hole collapsing if the HDD method had been applied along with the welding associated with this process.

At advance speeds of up to 250mm/min, it was possible to install a 36m pipe within four hours. A coupling process generally involves one to two shifts.

The machine tunnelled through sand, silt and in some cases clay. Unanticipated old banking reinforcements made of wood and water stones were also driven through. Obstacles crushed by the mixed-soil cutterhead and cone crusher were pumped to the surface through the slurry line. As the invert line ended in an insertion structure in the Ems, the machine was to be recovered in there. The required accuracy of only a few centimetres was easily achieved by the surveying system deployed.

Installation of gas pipelines

The next phase of development was the

Left: Crossing the Hartelkanaal in Rotterdam, summer 2010; Left, below: A rendering of the pipe thruster

direct installation of product pipes. This was preceded by another lab-quality load test conducted on the pipeline coating. The test showed the pipe thruster would not cause any damage to the polypropylene (PP) coating and the green light was given to the Dutch gas supplier.

Following successful testing, a total of five projects were realised in the Netherlands in 2010. Crossings of between 360 and 540m in length bypassing obstacles such as archaeological sites, smaller rivers and a railway line formed part of the approximately 500km long North-South Route in 48in (1.22m) intended for transporting gas throughout the Netherlands in the future. This first-time installation of gas pipelines in the Netherlands represented a key milestone in the progress of the method.

The most unusual of these five projects was the 540m crossing of the very deep and busy Hartelkanaal in Rotterdam's Europoort in summer 2010. What made this project so different was the required course depth of 30m under the ground surface and the ensuing very steep access and exit angles of 10 degrees and 12 degrees, respectively (approximately three to five degrees had been the standard to date). A second slurry pump, located within the pipeline, was needed to overcome the altitude. The excavation through sand and silt was completed in September 2010. The entire pipeline was installed in 10 sections of 54m each over a period of two weeks.

The NSTT (Netherlands Society for Trenchless Technology) awarded the client and construction company the 2010 No-Dig Award for successful realisation of the project using this alternative installation method. This No-Dig Award was the second of its kind with the first award presented in Moscow in 2008 by the ISTT (International Society for Trenchless Technology). The innovative process was also nominated for the Hermes Award at the Hannover Fair in 2008. And the method received the International Pipeline and Offshore Contractors Association New Technologies Award in San Francisco in 2009.

Another milestone was achieved during the last two of the five Dutch projects (both over 500m long) involving first-time crossing of a railway embankment using the method. The overburden under the railway tracks on the Zwolle-Almelo line totalled 15m. The 48in (1.22m) gas pipeline



Above: The pipe thruster on display at Messe Hanover—where it was first launched by Herrenknecht

was thrust in one single piece and inserted into the target pit together with the machine with only 150t of thrust force. Advance rates of up to 124m were achieved in a shift lasting approximately ten hours.

US debut

The method celebrated its successful premiere in the US in August 2010. Unlike the 48in (1.22m) pipelines already installed in Germany and the Netherlands, the three gas pipeline crossings realised in Florida only involved outside diameters of 30in and 36in (762mm and 914mm). The drive lengths of 119 to 226m were shorter than trialled in Europe. Considering the lack of space, the microtunnelling machines used for these very small diameters cannot be fitted with a hydraulic power pack which means that the drive length is currently limited to approximately 250m for pipeline diameters which are smaller than 40in (1,016mm) o.d.

One particular feature of the first American direct pipe project is its alignment. Unlike previous alignments, the pipeline under Highway 70 not only had to

be installed with a vertical curve (R = 914m) but with a horizontal one (R = 1,828m) too. The navigation system featuring a gyroscope and electronic water levelling system kept the machine on the specified space curve. After three days of tunnelling, in three day shifts of 12 hours each, the site team had installed the 215m gas pipeline in one go. The HK500PT pipe thruster used required average thrust forces of 15t and a maximum thrust of 28t.

In early 2011, the direct pipe boring machine, including a 36in (0.9m) pipeline, was extracted for the first time using the pipe thruster in the third project performed in the US. After tunnelling through 102m, the machine was recovered to the surface with the aid of the pipe thruster together with the pipeline, the cutterhead replaced and reinserted into the bore hole—all within a single day. During the pullback process, the bore hole was filled with bentonite to prevent it from collapsing. The cutterhead required changing after encountering an unexpected rock formation that could not be passed through without disc cutters. The remaining 124m were then installed over a period of three days.

Outlook

The direct pipe method allows for fast

installation speeds. This has made the process a technically practical alternative to HDD and microtunnelling. The improved installation reliability in difficult soil—compared to HDD—as well as the economic advantage over conventional pipe jacking translate into considerable competitiveness on the part of this method.

The fact that in the past it has always been possible to overcome invariably new challenges is already an indication that the limits of the process will shift increasingly from one year to the next making areas of application ever more obvious—something which was difficult to assess in the early days. It will therefore remain exciting for observers and especially for those wishing to use the method.

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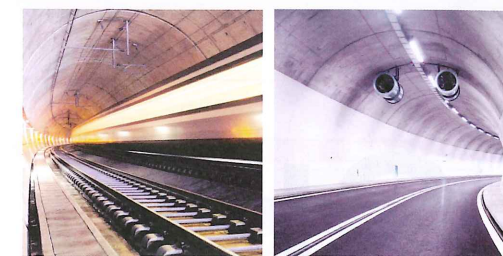
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OSSA JV wins Esti headrace repair contract in Panama

A joint venture comprising Spain's **OSSA**, Italian TBM-marker **Seli** and Swiss engineering design firm **Lombardi**, has signed a US\$53 million design-build contract for the repair of the Esti headrace tunnel in Panama.

The contract requires urgent, major repair and lining work to the 7.5Km, 9m-diameter pressure tunnel, which has collapsed in several places, causing a shutdown of the generating plant. As the plant plays a vital role in Panama's generating capability, the tunnel failure dictates a fast-track completion, which will see work being carried out simultaneously across several adits.

The first part of the two-phase operation will involve removing the collapsed material, followed by NATM stabilisation. The second stage will be to apply an in-situ concrete lining using sliding formwork.

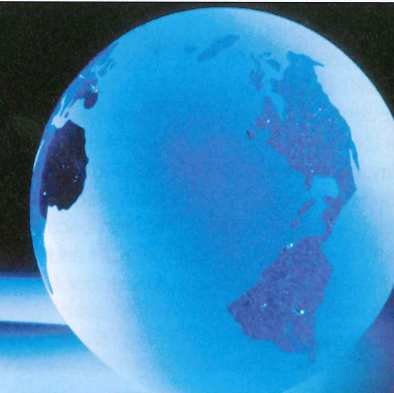


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An example computational fluid dynamics pattern



Asix-year longing for a return to the tunnelling industry has come to an end as Karl Else joins ventilation and fire safety specialist Mosen in the role of engineering director. Specialising in computational fluid dynamics (CFD), he leaves the world of office space fit-outs and large data centres to come back into the industry fold and bring his 22 years of experience to bear on tunnel ventilation.

Else's career began with Mott MacDonald's Chunnel division in 1989. "As with a lot of things, my entry into the tunnelling industry was vaguely accidental. I finished my degree in Mechanical Engineering with a bit of an automotive bias," says Else. "The degree was traditional and there were lots of deals with companies like Jaguar and an overall obsession with radiator fins. I thought that's where I would end up as I was interested in all things oily. I even had a Perkins job offer, but the recruitment guy representing Mott MacDonald got in the week before. I had a friend in London, so I thought I would go to the pub the night before for a drink, head to the interview the next day, expense the whole thing and then head to Perkins."

"Things didn't go quite to plan. I showed up late and the guy didn't seem to be expecting me. He asked me if I had heard of CFD—fortunately I had read about it in a magazine advert, said yes, and the relief on

his face was phenomenal. I was bundled down the corridor to a couple of guys just setting up the business and they hadn't even got a computer yet, but next day I got the call offering me the job. I liked the idea of being in London so I accepted."

Despite what he thinks of as a terrible premise for a career, Else decided he liked the work and general tunnelling. "Although I feel like I'm on the periphery of the tunnelling industry, it's really satisfying to say 'I helped build that'—much more so than a barbed wire surrounded data centre. I'll have to get more involved with the industry now I'm back, I feel a bit guilty that I wasn't more so last time. I don't consider myself a tunneller, more an engineer pleased to be working in tunnels."

Else adds, "I've always been forced to 'lone wolf it', working alone as a specialist. With Mosen's expansion that may change, but that's how I am still at the moment. I worked temporarily with Hatch Mott in New York in 2000 before leaving Mott MacDonald for Faber Maunsell in 2002. There I was slowly moved away from the tunnelling Maunsell side to the more building service-oriented Faber side. After that I went to HurleyPalmerFlatt in 2005 where I became frustrated with building services and just moved to Mosen this November. I missed tunnels."

"It's hard to think of specific high points in my career. There's just a general level of

satisfaction in getting a practical solution to a job and getting it out the door. The Chunnel stands out as a big one. Even though it bankrupted people, from an engineering standpoint it is still an amazing achievement. I also helped determine that the pitch at the new Wembley Stadium would not be well ventilated while at Mott. This was just before the old Wembley was knocked down. People weren't sure why the pitch was so good and ventilation was one consideration."

Else adds, "One interesting experience I had was in a nuclear reactor basement at Trawsfynydd. I was at one point told 'don't stand just there, it's a bit dosey'."

To budding engineers Else says, "The biggest mistake I made was staying in one place too long. I was with Mott for 13 years and it didn't do them or me any favours to become part of the furniture. I would have learned more and quicker if I had moved around companies and sectors. Don't be promiscuous with jobs, but make sure you stretch yourself and keep things fresh."

"The other thing I would say is if you work in simulations in an office, for God's sake go out to the sites and look at the kit. Get out into the world and stay grounded, or risk getting out of touch."

"It is dangerous otherwise. Some things look great in theory but are utterly abstract and impractical. You get a much better understanding of what you do if you visit whenever possible."



Above: Else joined Mosen last month

Business directory

To advertise on this page call Tom Willard on: +44 (0)20 7406 6599 or email twillard@tunnelsonline.info

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12 - 13 JANUARY 2012

Shotcrete 2012 (Spritzbeton-Tagung), Tyrol, Austria

Prof Wolfgang Kusterle and his team are hosting this conference and exhibition for shotcrete specialists. The conference will be in German with some presentation in English, and English summaries of all presentations will be available. The Final program will be available by October 17, 2011. For more information e-mail: spritzbeton@kusterle.net

21 - 22 FEBRUARY 2012

Fire Protection and Safety in Tunnels Asia, Singapore

With Asia having some of the longest tunnels in the world and some of the most rapid developments occurring globally this is the best platform to uncover current and future projects across the region and pinpoint the best strategies to ensure fire design is implemented accordingly. The conference will also include a site visit to a Singapore tunnel. More information is available at <http://www.arena-international.com/fpstasia/>

14-16 MARCH 2012

ISTSS 2012, New York, USA

Forum with the themes of risk and security, human behaviour, passive fire protection and construction, active fire protection & fire fighting, ventilation and fire dynamics. The focus is shifting more and more towards security, with new the terrorist threats and the focus on how to solve these problems increasing. Organised by SP Technical Research Institute of Sweden - Fire Technology. For more information see www.istss.se, email info@sp.se or tel.: +46 10-516 50 00

20-22 MARCH 2012

3rd Brazilian Congress on Tunnels & Underground Structures & Int Seminar 'South American Tunnelling', Sao Paulo, Brazil

The event will include 11 topics and be run with an exhibition and technical visits to World Cup sites etc. Now more than 70 subscribers reported. Two days will be reserved for a refresher course and training. Contact Executive Secretariat, Acqua Consultoria on tel.: +55 11 3868 0726, email 3cbt@acquacon.com.br or see www.acquacon.com.br/3cbt.

22-23 MARCH 2012

Int Sym 'Practices & Trends for Financing & Contracting Tunnels & Underground Works', Royal Olympic Hotel, Athens, Greece

Organised by the Greek Tunnelling Society. Contact GTS on tel.: +98-21-88630496, email bakojon@otenet.gr or see www.tunnelcontracts2012.com

27 - 29 MARCH 2012

INTERtunnel 2012, Turin, Italy

The tenth edition will be staged at the Lingotto Exhibition. Italy's only regular exhibition on tunnelling technology but also with great international input. Italy claims the greatest number of tunnels in Europe and also has cross-border projects between Turin and Lyon, France, and also the Brenner Base Tunnel to Austria. Alongside Expo Ferroviaria rail exhibition. For more information email: intertunnel@mackbrooks.com or tel. Arianna Rosini on telephone +44 (0)1727 814 400

12-14 APRIL 2012

UnderCity 2012, Dubrovnik, Croatia

Colloquium on using underground space in urban areas in south-east Europe. Contact Tanja Rabar on tel.: +385-51-410-447, email tanja.rabar@hubtig.com or see www.undercity2012.com.

24 - 26 APRIL 2012

3rd Int Conf on Shaft Design & Construction, London, UK

Organised by the Mining Technology Division of the IMMM and the BTS at 1 Carlton House Terrace. The scope includes all areas of design and construction of both civil engineering project and mine shafts. Contact Paul Harris at IOM Communications by email paul.harris@iom3.org, tel. +44 (0)20 7451 7302 or see www.iom3.org/events/sdc2012.

18 - 23 MAY 2012

World Tunnel Congress WTC 2012 & 38th General Assembly of the ITA, Bangkok, Thailand

Organised by the Thailand Underground & Tunnelling Group (TUTG) of the Engineering Institute of Thailand with the ITA, the theme is 'Tunnelling & Underground Space for a Global Society.' For more information email: secretariat@wtc2012.com or visit www.wtc2012.com

29 MAY - 01 JUNE 2012

SSCS - Numerical Modelling, Strategies for Sustainable Concrete Structures, Aix-en-Provence, France

Organised by the Association Francaise de Genie Civil (AFGC). Contact Nadjet Berrahou-Daoud on tel.: +33 1 44 58 24 29, email afgc@enpc.fr or see www.afgc.asso.fr

24 - 27 JUNE 2012

North American Tunneling Conference (NAT), Indianapolis, Indiana, USA

UCA's biannual conference, which has continued to grow each year with more exhibits, technical sessions & attendees. More information regarding housing and registration will be available at <http://uca.smenet.org/> in spring 2012

18 - 21 SEPTEMBER 2012

Eastern European Tunnelling Congress, Budapest, Hungary

The Hungarian Tunnelling Association is organizing the 1st Eastern European Tunnelling Congress to share experiences and exchange knowledge of design, construction management, research results and technical developments of tunnels completed by the regional associations and experts. The planned regional sub European conference is open to all other co-organizers and participants as well as to those who having ongoing or completed projects, research works in this area.

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition, which is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Editor, 'Tunnels & Tunnelling International', Boundary House, 91-93 Charterhouse Street, London, EC1M 6HR, United Kingdom. Fax: +44 20 7936 6826 Email: editor@tunnelsandtunnelling.com Web: www.tunnelsandtunnelling.com

ABSTRACT SUBMISSION: 2 JANUARY 2012. More information at <http://www.eetc2012budapest.com/>

7 - 9 NOVEMBER 2012

13th World Conference of ACUUS, Singapore

The Associated research Centers for Urban Underground Space (ACUUS) is presenting 'Underground Space Development - Opportunities and Challenges.' The intent is to focus on new opportunities in a re-focus on developing the urban underground space as part of sustainable development, and the many challenges and issues that planners, developers, and engineers face. More information at <http://www.acuus2012.com>

BRITISH TUNNELLING SOCIETY

ALL BTS MEETINGS ARE AT THE INSTITUTION OF CIVIL ENGINEERS, LONDON, UNLESS OTHERWISE STATED, AT 17:30 FOR 18:00. TRADITIONAL BAR AND SNACKS WILL BE AVAILABLE AFTERWARDS.

15 DECEMBER 2011:

Cleaner Seas for Sussex

In order to treat the 95 million litres of wastewater generated each day by residents a new wastewater treatment works and 11km of new sewer were required. Now substantially complete find out how more than 11km of 1.8m and 2.4m diameter tunnels and associated shafts and pumping stations were completed. Speakers: Ben Green, Southern Water programme manager and Craig Reade, Costain project manager

19 JANUARY 2012

Tunnelling Induced Settlements in London Clay - Effects on Buildings

Of particular interest in view of the Crossrail and other major London tunnelling projects now in progress, this presentation will be made by Prof Robert Mair, Head of Civil & Environmental Engineering at Cambridge University and Chair of the Geotechnical Consulting Group, Dr Jamie Standing of Imperial College, London, and Dr Keith Bowers of London Underground Tunnels, Transport for London

16 FEBRUARY 2012

Chile Mine Rescue

A joint meeting with the MinSouth local society of the Institute of Materials, Minerals and Mining. Brian Robinson of Mine Rescue will describe the famous rescue of the 33 Chilean Miners in 2010 and the lessons for future rescue operations.

15 MARCH 2012

Report from the BTS Compressed Air Working Group

Presentation from Dr Donald Lamont, Hyperbaric & Tunnel Safety and Roy Slocombe, Director of Herrenknecht International

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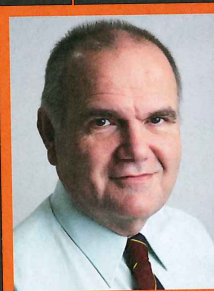
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