JULY 2010

tunnels & tunnelling INTERNATIONAL


12


59

Special report: Middle East & Africa

T&TI looks at the work in the Middle East and Africa including Abu Dhabi's sewers

Technical: Fibre reinforcement

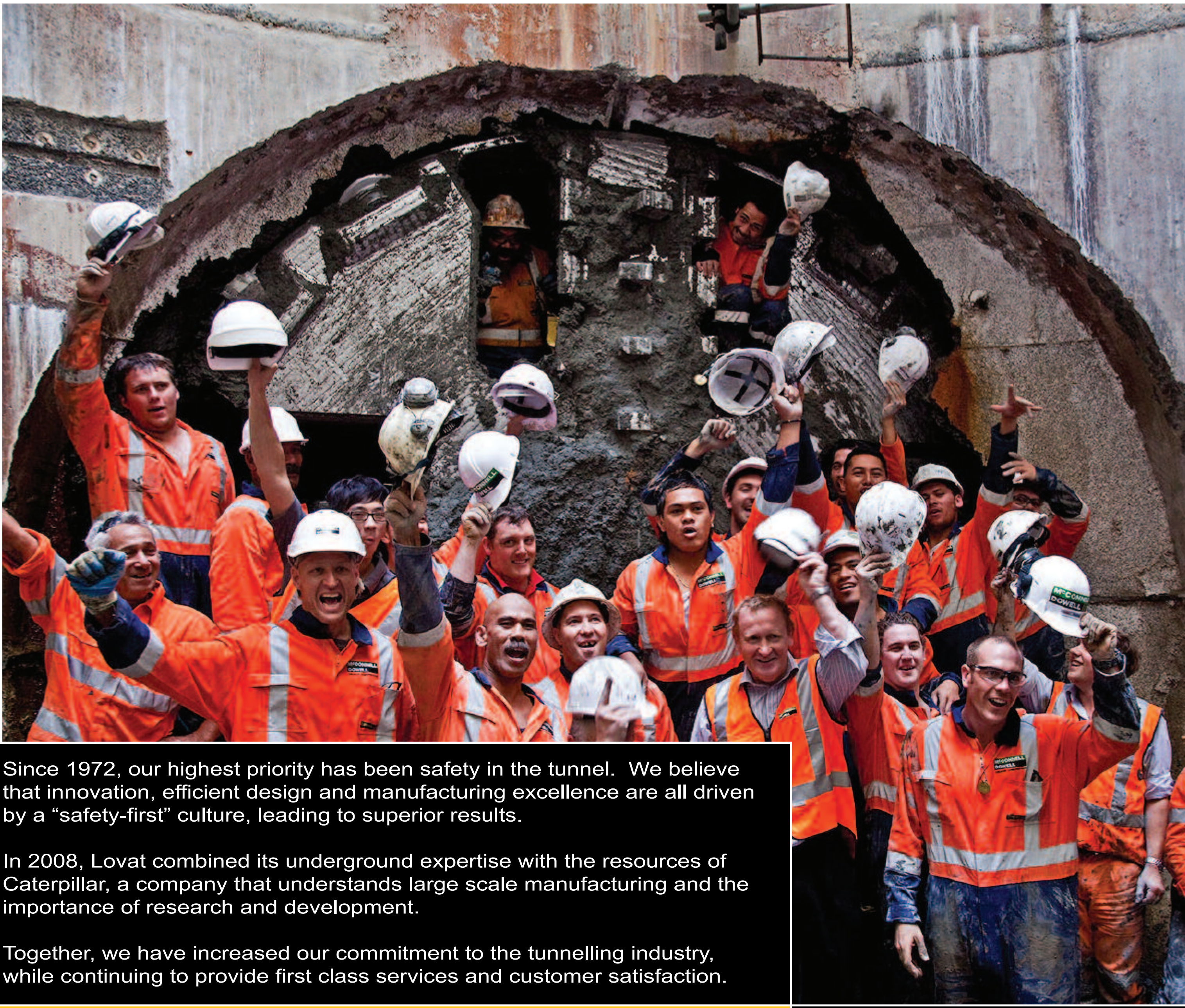
T&TI tackles the debate surrounding plastic and steel fibres in concrete

WWW.TUNNELSONLINE.INFO

Clearing Cairo's congestion

A look at works on Line 3 of the Cairo Metro

TUNNEL WITH CONFIDENCE START TO FINISH...



Since 1972, our highest priority has been safety in the tunnel. We believe that innovation, efficient design and manufacturing excellence are all driven by a “safety-first” culture, leading to superior results.

In 2008, Lovat combined its underground expertise with the resources of Caterpillar, a company that understands large scale manufacturing and the importance of research and development.

Together, we have increased our commitment to the tunnelling industry, while continuing to provide first class services and customer satisfaction.

Caterpillar is the world’s leading manufacturing of construction and mining equipment, diesel and natural gas engines and industrial gas turbines and a leading services provider through Financial Services, Caterpillar Remanufacturing Services, Caterpillar Logistics Services and Progress Rail Services. For More information on Caterpillar, Visit **CAT.COM**

AND BEYOND

www.lovat.com

LOVAT

A Caterpillar Company

Registered ISO 9001: 2000
Certificate No. 0020366

comment

contents

On the cover

T&TI looks at challenges Cairo's Line 3 has faced and its progress to date (page 23)

Price of the space race

TBMs are getting bigger. Herrenknecht will set a new record with a 15.55m EPBM on order for the A1 motorway between Bologna and Florence in Italy (page 6). Any discussion about the ever-increasing size of TBMs leads to the questions: how big can a TBM be?

The development of larger diameter TBMs has become the tunnelling industry's answer to the space race with the current target – Seattle's Alaskan Way Viaduct Replacement Tunnel (subject to approval of course). According to Alistair Biggart in his Harding Prize lecture earlier this year, there is no obvious limit to TBM growth.

There are barriers to overcome such as increasing torque with stronger gearing and higher-powered motors. The thrust might need to be addressed, introducing more rams or the segments being thrust from will need to be developed to withstand the greater thrust.

More durable cutters are needed, especially on the outside edges of the TBM where wear is greatest, that still keep the TBM and the project economical. Developments will need to minimise maintenance to cut down on face interventions, which can be high risk. This may mean that the larger diameter TBMs are restricted to shorter tunnel drives.

There are also transportation issues. Shipping of TBMs is usual done by heavy loading companies that use a mixture of barges and trucks to get the machinery to site. The TBM is segmented for transportation. Earlier TBMs had the cutter face shipped as a single element but the new larger machines have had these segmented. The crucial factor here is how small manufactures can make the largest single shippable component.

The main bearing would need to be segmented or it could limit the future size of TBMs. On EPBMs the screw conveyor could also pose challenges in its segmentation.

But as the TBMs grow larger so must the supporting infrastructure. Muck disposal systems will need to keep up with the growth. If using a slurry machine, the slurry treatment plants will need to grow, as will the number and size of slurry pumps. In an urban situation like Seattle, you need to review how the muck is removed from the site, as the city cannot become congested with trucks. Neither do many have much space left for landfill, at least not at a reasonable price.

TBM manufactures wear their records with pride so I am sure they will be going all out to build the biggest. It will be interesting to see how long Italy's A1 motorway will hold the title for. Not long we suspect.

Jon Young

ZURICH: EXCELLENT TUNNELLING.

European cities like Zurich – whose importance is disproportionately high in comparison to its middling population size – are investing in large projects to both maintain and develop their attractiveness. Efficient traffic systems are a vital factor for a location in this respect. Railway projects with a total length of 27 kilometers are currently under construction in the Zurich region. The most important recent project is the Diameter Line – a dual track railway connection right through the center of the city which will connect the new Löwenstrasse underground station with the Oerlikon station via the 4.4 kilometer long Weinberg Tunnel. The Weinberg Tunnel Consortium is using the convertible Herrenknecht S-451 Mixshield (Ø 11.24m) which is designed to tunnel in both hard rock and beneath the Limmat River in groundwater. This high-tech machine is operated by an excellent team of experienced tunnellers. Several times, complete lining rings – consisting of 5 + 1 segments – have been installed in less than 15 minutes.

Herrenknecht tunnel boring machines for the excavation of railway and highway tunnels have already been used successfully several times in Zurich, for example for the Zimmerberg Base Tunnel and the Islisberg Tunnel. Furthermore, from 2017, Zurich will have a railway connection to Milan via the new Gotthard Base Tunnel, reducing the journey time to only slightly more than two and a half hours.

ZURICH | SWITZERLAND

PROJEKTDATEN	CONTRACTOR
S-451, Mixshield (convertible) Diameter: 11,240mm Installed power: 3,200kW Tunnel length: 4,416m Geology: Molasse, unconsolidated material	ATW Arge Tunnel Weinberg: Implenia Bau AG, Wayss & Freytag AG, Bilfinger Berger AG, PraderLosinger SA

Herrenknecht AG
D-77963 Schwanau
Phone +49 7824 302-0
Fax +49 7824 3403
marketing@herrenknecht.com

www.herrenknecht.com

HERRENKNECHT Tunnelling Systems

Permission sought for Dart line

IRELAND

Application for a Railway Order granting planning approval for metro development in Dublin city centre was lodged last month with Irish planning committee An Bord Pleanala. The application by statutory transport company Córas Iompair Éireann (CIE) represents a further milestone in the project, which is considered the most important rail development under the government's Transport 21 investment programme.

CIE will deliver the second high capacity metro line, known as Metro West, on Dublin's proposed Dart Underground network. The twin bore tunnels for the metro will be roughly 7.6km long and will connect the Northern and Kildare rail lines.

Dart Underground will link all of Dublin's rail systems—Commuter, InterCity, Luas and Metro—to form an integrated and seamless transport network that will treble the numbers travelling on the Greater Dublin rail system to more than 100 million passenger journeys annually.

The scheme is part of Transport 21, an infrastructure plan announced in 2005 to greatly expand Ireland's transport network. The plan will see a total investment of EUR 34bn (USD 42.6bn).

Ireland's Minister for Transport Noel Dempsey welcomed the news of the submission of the Railway Order application. "Today marks an important stepping stone in our efforts to increase and improve public transport in Ireland," said Dempsey.

He added, "this government is committed to investment in important infrastructure that will serve us for many generations to come."

The Railway Order is the equivalent of a planning permission for new rail schemes and, if granted, will authorise CIE to construct, maintain, improve and operate the Dart Underground. The project will involve the construction and operation of approximately 8.6km of new rail (7.6km of which will be in tunnels) from the CIE Inchicore Works to tie into the Northern mainline south of East Wall Road and north of the Docklands area. The project will be managed on behalf of CIE by Iarnrod Eireann (Irish Rail).

Subject to the granting of the Railway Order, construction is expected to start in 2012, with the system being operational in 2018. The tunnels will be constructed using two TBMs, launching from the Docklands, at an average depth of 24m below ground level.

The underground stations will be constructed using techniques that will minimise the effect for the local residents, communities and environment.

There is potential for more than 75 per cent of the spoil from the construction of the project to be removed by rail.

News in brief

Bachy scoops award
Bachy Soletanche, in conjunction Laing O'Rourke and Garassino Eng, has been named the winner of the ICE Engineering Excellence Awards' Innovation Award for its work on the GBP 5M (USD 7.5M) Isle of Grain Pump House Cofferdam project.

Prime Ministerial Tunnel
The Indian government is planning to construct an underground tunnel, 3km long, between Prime Minister Monmohan Singh's residence and the nearest airport, Safdarjung, to avoid the heavy traffic congestion caused by the VIP movements.

Transit most important
A citizen poll in Ottawa, Canada, has revealed that transit and transportation will be the most important issues in this autumn's municipal election. Nearly three in 10 named transit and transportation the top issue. That's triple the number who named the second issue, high taxes.

Brighton TBM arrives on site

GREAT BRITAIN

Two TBMs have been delivered for the construction of tunnels for Southern Water's new 11km sewer in Sussex, constructed by 4Delivery, a consortium comprising United Utilities, Costain and MWH.

Magnor Plant, the in-house plant hire company of construction and infrastructure business Morgan Sindall, won the GBP 2.1M (USD 3.1M) contract for hire and refurbishment of the TBMs, which will be on loan for one year until June 2011.

The TBMs have a 2.44m internal diameter and will be tunnelling between eight and 40m below ground level. The new 11km sewers are part of Southern Water's scheme to transfer wastewater from Peacehaven, Telscombe, Saltdean, Rottingdean, Woodingdean, Brighton and Hove, to a new wastewater treatment works and outfall at Peacehaven.

Leading up to the start of construction, there had been several years of delays because of planning objections. Final permission was granted in October.

Giant TBM for Italy tunnel

ITALY

The world's largest TBM will be built and start boring next year in Italy. The 15.55m diameter, 120m long, Herrenknecht EPBM will be used on the extension to the A1 motorway between Bologna and Florence.

The 4,300t machine with its 12,000kW cutterhead power will be used to bore the Sparvo Tunnel, consisting of two parallel-running 2.5km tubes, both of which will accommodate a three-lane road. The profile of the tunnel will set a new record in mechanised tunnelling as far as the drilling diameter is concerned.

Italian contracting company Toto Construzioni Generali will carry out the tunnelling works in loose soils with a presence of gas using EPB technology. The project was awarded to the Vianini Lavori/Toto Construzioni Generali/Profacta joint venture by the client Autostrada per l'Italia.

Construction of the tunnel is considered to be the most challenging part of the overall project, due to the size and geological conditions. The Italian contracting company Toto Construzioni Generali decided to use mechanised tunnelling technology to improve work safety and to accelerate the works.

Preparations for the assembly of the record-breaking TBM have already started in Schwanau. A tight time schedule has been set for the construction of the Sparvo Tunnel. In line with the current planning, the machine is expected to start tunnelling near Florence towards the north as early as the first half of 2011. The 6-7 lot is the last section of the Variante di Valico project, which will considerably reduce the travelling time between Bologna and Florence for up to 90,000 vehicles per day after the alternate route is opened according to schedule at the end of 2013.

Doha metro terminal works

QATAR

Construction has started for the New Doha International Airport (NDIA) Terminal Metro Station in Qatar. It's the first underground metro station in Qatar and will be the terminus for the future Doha Metro line, linking the city with the main NDIA terminal.

The Government of the State of Qatar, represented by the NDIA steering committee, commissioned Mott MacDonald in 2008 to design the metro connection from the airport to the rest of the network.

Working with sub consultants Aedas, Mott MacDonald developed a metro system based on conservative parameters and space proofing of 1.3km single track twin bored tunnels, and a 305m long by 25m wide and 20m deep cut and cover underground station.

In addition to the design of the fully space proofed structural shell of the station box, the project included rail alignment and systems, fire safety, civil and structural, electrical and mechanical engineering.

The airport is expected to open in 2011, and Mott MacDonald is still providing "construction support services" to NDIA until construction on the station box is completed, also anticipated for 2011, said Mert Yesugey, project manager with Mott MacDonald.

Beskydy reconstruction

UKRAINE

The Ukraine's largest state-owned railway company, Ukrzaliznytsia, in cooperation with European Bank for Reconstruction and Development (EBRD), is planning to start a massive reconstruction of the single-track Beskydy railway tunnel in the Transcarpathian region.

Under the terms of the project, both sides will start the reconstruction of the tunnel, which will be completed through the construction of access roads, as well as a new two-way 1.8m railway tunnel with 115m2 cross-section area. This will increase the tunnel's capacity in the Europe-Asia direction.

The project will be officially launched after the contract is signed and the contractor should be named soon.

According to Ukrzaliznytsia, Austrian company PORR Group and Spanish company OHL Group are both among the main contenders.

The cost of the project is USD 200M, of which almost USD 120M is expected to be provided by EBRD, with the remaining USD 80M coming from Ukrzaliznytsia.

The USD 120M loan will be granted for 15 years with a 6 per cent interest rate.

According to sources in Ukrzaliznytsia, nearly USD 47M of the funds will be invested in the establishment of high-speed railway traffic, as well as the purchase of modern passenger cars.

Mark Magaletsky, an official representative of EBRD, said that the project is expected to be implemented during the next three to four years.

The tunnel, built in 1886, serves as the fifth Pan-European corridor.

News in brief

Maidenhead water main
A TBM is being used to tunnel underneath a Berkshire town by contractors laying a GBP 2.3M (USD 3.4M) water main. South East Water is using the specialist technique to install a 75m section under a watercourse in the Town Moor area of Maidenhead. The pipe will provide an extra 2.5 million litres of water to the town.

New drill for Ditch Witch
Ditch Witch announced the release of its most powerful All Terrain directional drill. The JT100 All Terrain is built for extended-range bores and installation of large-diameter pipe. The 268-hp (200 kW) drill has 100,000 lb (445 kN) of pullback and 12,000 ft·lb (16 270 N·m) of torque. A patented two-pipe drilling system allows the machine to do installations in most ground formations, including solid rock.

LiuGong names NA chair
James William Donoghue has been announced chairman of the board of directors for LiuGong Construction Machinery North America. Since 2008, Donoghue has been president of LiuGong Machinery, Latin America.

Four tunnels completed in NYC

USA

Apart of New York City's "Tunnel to Nowhere" came a step closer to reality last month when the first of two TBMs finished a series of short rail tunnels below Manhattan's Grand Central Station.

The Robbins Main Beam TBM was used by the Dragados/Judlau joint venture. Altogether, the machine excavated 5.2km of tunnel since its 2007 launch, averaging 16m a day in the last month of boring.

The completion is an important milestone for the East Side Access project, which was stalled in the 1970s due to lack of funding.

A second Double Shield TBM is preparing to embark on its third of four tunnels. The short tunnels, four to each TBM, will ultimately lead to the upper and lower departure and arrival platforms of two main stations currently under construction.

The TBM was retracted at the end of each tunnel heading using specially designed, hydraulic side and roof supports to move past installed ring beams and rock bolts. "The bolted cutterhead, in five sections, was the best possible design for boring multiple tunnels and retracting back through the ring steel," said Kerry Clark, Robbins Field Service Superintendent. The hydraulic extensions, combined with the removable cutterhead pieces, allowed the entire machine diameter to be reduced from 6.7m to just 6m.

Crews maintained good advance rates despite difficult project conditions. At one point the parallel TBM excavations were separated by a slim 1.5m thick pillar of rock, requiring the machine to operate at 45 to 50 per cent gripper and thrust pressure. Much of the drive was also done with a live subway tunnel 1.5m overhead.

The Metropolitan Transportation Authority's East Side Access Project will connect the boroughs of Manhattan and Queens below the East River, providing rail service to 160,000 daily customers.

The rail line will take thousands of cars off of surface streets, saving commuters an estimated 30 to 40 minutes of travel time. Tunnelling in soft ground on the Queens side of the project is expected to start later this year. The completed East Side Access line is scheduled to begin service in 2016.

Knights awarded James Clarke Medal

GREAT BRITAIN

At its Annual General Meeting in May, the British Tunnelling Society (BTS) announced the award of the prestigious James Clarke Medal to Martin Knights, then of Jacobs Engineering, for his long association with the British tunnelling industry, many contributions to the work of the BTS and international achievements. Knights was not present at the meeting as he was still in Vancouver carrying out his duties as outgoing President of the International Tunnelling Association.

Consequently the new BTS chairman, Bob Ibell, said that the medal would be presented at another occasion.

Effective 15th June the appointment of Martin Knights as Global Director for Tunnels for UK-headquartered engineering consultancy Halcrow was announced.

Also at the BTS AGM, three new members of the general committee were elected. These were Mark Kirkbride (ITM), John Cochran (Morgan Est) and Ian Blight (Halcrow). Ibell commented that the election results were very close, from a low turnout.

Abu Dhabi's first EPBM

UAE

Testing of the first TBM to be used in the Middle Eastern emirate of Abu Dhabi will get underway this month in Germany. The 6.3m diameter Herrenknecht EPB machine is one of eight to be used in construction of a 40km deep sewer tunnel by the Abu Dhabi Sewerage Services Company (ADSSC).

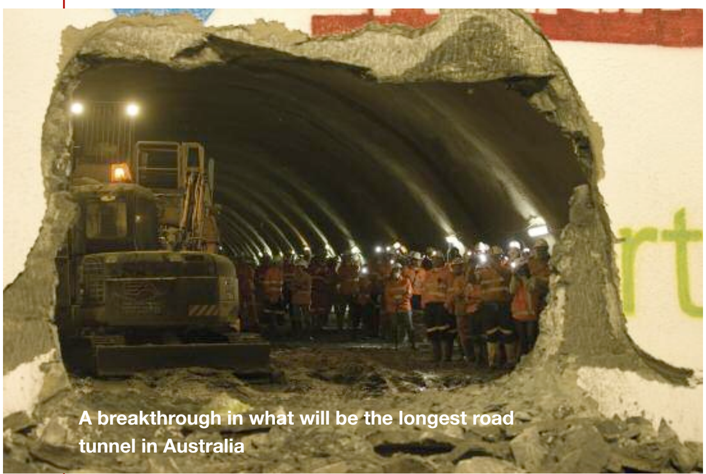
The new tunnel runs from 30m depth to 100m and replaces a network of 50 pumping stations and forced wastewater mains. It is part of a wider plan to increase wastewater collection and treatment capacity in the emirate which is the capital of the United Arab Emirates and has a population of around one million.

The bore is being driven under three contracts, the first of which has been awarded to Italy's Impregilo and involves the use of three 6.3m EPB TBMs. ADSSC has selected preferred bidders for the two remaining bores, but the contracts are currently being evaluated by the emirate's highest authority the Abu Dhabi Executive Council. Further contracts for linking sewers that connect to the tunnel, and a major pumping station are still being assessed by ADSSC.

Testing of the other two TBMs for the Impregilo led bore is on a one month lag with machine two testing set to take place in August. The first EPB is scheduled for installation in the launch shaft in October with the bore commencing in December.

Construction of the first 14.5km section is set for completion by June 2013.

Airport Link breakthrough



A breakthrough in what will be the longest road tunnel in Australia

AUSTRALIA

A 135t roadheader made the first breakthrough in the 5.1km Airport Link project, Australia's longest road tunnel, in Brisbane last month.

The breakthrough occurred in the northbound tunnel as the roadheader travelled south from Windsor and cut through the tunnel face at Bowen Hills, 22m below the surface of Lutwyche Road.

"The roadheader that has just broken through is one of 11 machines excavating the 1.5km distance of tunnel between Truro Street, Windsor and Federation Street, Bowen Hills," said Gordon Ralph, project director at Thiess John Holland, the company designing and constructing Airport Link.

Construction of the tunnels is being undertaken using a combination of TBMs, roadheader machines and cut and cover tunnelling.

The Thiess John Holland joint venture is contracted by BrisConnections who is responsible for delivering the Airport Link project together with Northern Busway and Airport Roundabout Upgrade, an AUD 4.8bn (USD 4bn) infrastructure investment by the State Government.

A total of 17 roadheader machines are now carving out the Airport Link and Northern Busway tunnels – the largest number of roadheaders to be used on an Australian project.

BrisConnections Chairman Trevor Rowe said, "the efforts to date bring us one step closer to the operation of Airport Link, scheduled to open in the next two years."

Thiess John Holland is also preparing to launch the first TBM from Kalinga Park, Toombul to excavate the Airport Link mainline tunnel this month.

News in brief

Drain acquisition

Geotechnical contractor Hayward Baker announced its acquisition of Nilex Construction Group's wick drain and earthquake drain assets. Now renamed HB Wick Drains, it operates as a product-specific division of Hayward Baker and will be led by James Cramer, the long-term leader of Nilex's wick drain business.

Daros bought out

Power train and safety technology provider Federal-Mogul last month acquired the Daros Group. Details of the transaction were not disclosed in Federal-Mogul's announcement. Daros Group is a supplier of high technology piston rings for large-bore engines used in industrial energy generation and commercial shipping, with operations in China, Germany, and Sweden. Prior to the buy out, the group was privately owned.

Calls for Crimea tunnel

UKRAINE

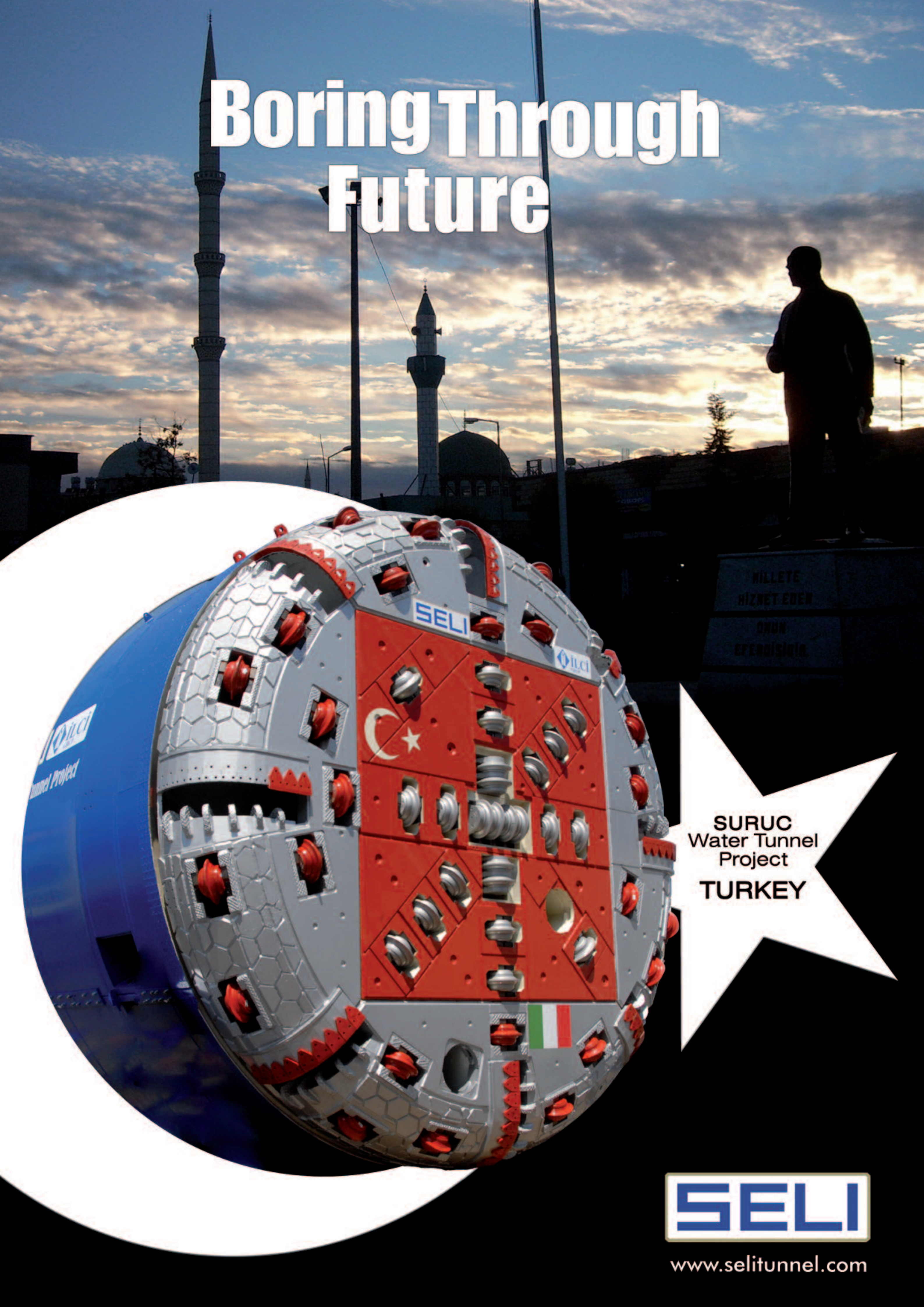
Serhiy Kunitsyn, envoy of Ukrainian president Viktor Yanukovych to Crimea, said it is necessary to build a road tunnel for transport under the Kerch Strait.

"At least at present, the arguments for a road tunnel are very persuasive for me," Kunitsyn said at a press conference in Crimea's capital Simferopol last month.

Kunitsyn noted that a design for such a road tunnel was drafted 10 years ago when he was the prime minister of Crimea.

He said that at that time he had also supported the idea of constructing a tunnel under the Kerch Strait.

The strait connects the Black Sea to the Sea of Azov.


Boring Through
Future
SURUC
Water Tunnel
Project
TURKEY
SELI
www.selitunnel.com

New Irvington Tunnel contract

USA

The San Francisco Public Utilities Commission (SFPUC) has awarded the contract for the New Irvington Tunnel Project to the Southland Contracting/ Tutor Perini Corporation joint venture. Their bid of $226.6 million was the lowest qualified, and came in $26.6 million below the SFPUC's engineers' original estimate.

The new tunnel will extend 3.5 miles and have an internal diameter of approximately 8.5 to 10.5 feet. It will lay parallel to the existing tunnel between the Sunol Valley south of Highway I-680 and Fremont, California.

New Irvington is designed to provide a seismically-upgraded connection between water supplies from the Sierra Nevada Mountains and the Alameda Watershed to Bay Area water distribution systems. Once complete, the tunnel will provide the enhanced ability to reliably deliver water to customers after an earthquake while allowing the SFPUC to take the existing tunnel out of service for maintenance and repair.

Construction on the project is expected to begin in September 2010 with completion anticipated in early 2014. It is a key part of the SFPUC's $4.6 billion Water System Improvement Program (WSIP) to repair, replace, and seismically upgrade the aging Hetch Hetchy Water System. WSIP includes more than 80 projects spanning seven counties from the Central Valley to Downtown San Francisco.

Limerick Tunnel to open

IRELAND

The Limerick Tunnel under the River Shannon in Ireland is expected to open to traffic late this month.

Construction work on the tunnel, which cost more than EUR 500M (USD 612.7M), began in August 2006. The tunnel is one of the largest projects undertaken in the western region of Ireland.

The project involves the construction of approximately 10km of new dual carriageway, along with associated link roads and side roads.

The tunnel is the fourth crossing of the River Shannon in the environs of Limerick City.

The crossing involves a roughly 900m immersed tube tunnel, linking the townland of Coonagh, on the northern bank, with the townland of Bunlicky on the southern bank of the Shannon.

The work is being carried out by a Strabag/John Sisk & Son/Lagan Holdings/Roadbridge joint venture. Dutch company Van Oord carried out dredging work for the tunnel trench.

Another Dutch company, Mergor, carried out the immersion process of floating the tunnel elements out into the Shannon.

Atlas Copco launches drills

SWEDEN

Atlas Copco has launched three new heavy duty versions of its COP 1800 series hydraulic rock drills, intended for tough face drilling in underground mining and tunnelling projects.

"We want the rock drills to cut better with very rough applications in mining," said market support manager Fredrik Oberg. "Especially with rough applications, it's very specific to the site how long service intervals and downtime can last. With the new drills Atlas aims to double the amount of time between service intervals on specific jobs." A new feature is a side bolt design consisting of four front bolts and two at the rear, which Atlas said should minimise the risk of impact piston misalignment and secondary damages to internal parts. The front head of the rock drills has been strengthened to better handle demanding conditions. Having more material absorbs the energy that is generated by the shock waves reflected from the rock, protecting the drill. Atlas is currently field-testing the drills with scaling and blasthole drilling in Australia, and drifting applications in Canada.

News in brief

Rail line opens for World Cup

South Africa's Gautrain Rapid Rail Link opened one section, from OR Tambo international airport to Sandton, in Johannesburg, on 5 June, just in time for the FIFA football World Cup. The 160km/h train is the fastest on the continent. The entire Gautrain network is expected to be finished in June or July 2011.

Spain suspends tunnel construction works

The Spanish parliament voted to immediately suspend construction on a high-speed rail project that will include a tunnel under Barcelona's Sagrada Familia, the unfinished church by architect Anton Gaudi and a popular tourist attraction, while an alternative route is considered.

Athens metro secures loan

The European Investment Bank approved on 17 June a EUR 150M (USD 187.1M) loan to the Athens Metro for extension projects.

Projects to be funded include an extension towards Haidari and the completion of Aghia Paraskevi station on Line 3, and extensions on Line 2 toward Peristeri and Anthoupoli and toward Elliniko.

Channel Tunnel up for sale

ACQUISITION

The UK Government will auction off the Channel Tunnel Rail Link as part of a sale of key assets to bring some much-needed money into the country's depleted coffers. It expects to make at least GBP 1.5bn (USD 2.3bn) from the sale.

High Speed 1 (HS1) comprises the 68 mile (109.4km) railway from London to the Channel Tunnel and the four stations along the route, St Pancras International, Stratford International, Ashford International and Ebbsfleet International.

The new coalition government will get a huge boost from the privatization of HS1, which is used by Eurostar on its route between London and the Channel Tunnel, in its attempt to reduce the country's GBP 167bn (USD 242.7bn) annual debt.

The announcement, made a day before the emergency budget, invited bidders to complete a pre-qualification questionnaire by 9 July 2010. The successful bidder will become the owner of HS1 Ltd, which has a 30-year concession to run the line and stations.

Eurotunnel is interested in bidding for HS1 and is looking into the documents released by the Department for Transport (DfT) and the state-owned rail operator London & Continental Railways (LCR), said Eurotunnel spokesman John Keefe.

"We think that line has great potential," he explained.

Eurostar said the future deal will not affect their services and it will run trains on the line no matter who the operator is.

Citi and UBS have been instructed as financial advisors and are acting for the DfT and LCR, respectively.

Myrdal appointed at Normet

APPOINTMENT

Dr. Roar Myrdal has been appointed technical director of chemicals, mining and tunnelling at Normet International. Myrdal will take up his duties on 15 September this year.

In his role, Myrdal will be responsible for research and development of mining and tunnelling chemicals at the company. He will report to the director of tunnelling and chemicals Odd-Bjorn Kleven.

Dr. Myrdal has been working with concrete technology in industry, public road authorities and research institutes since the early 1990s and has a broad international experience in research projects and industrial cooperation. He has a doctoral degree in chemistry and holds an adjunct professorship in concrete technology at the Norwegian University of Science and Technology.

Before joining Normet International Myrdal worked as a senior scientist at Sintef (a leading international research institute and the largest independent research organization in Scandinavia) and as a member of the management group in Coin (Concrete Innovation Centre at Sintef).

During his time at Sintef, Myrdal was involved in various international projects. Previously, he was head of research and development at Rescon Mapei.

Myrdal played a key role in developing alkali-free accelerators for sprayed concrete. He has published more than 50 international papers and reports on chemistry and concrete technology related topics. Earlier this year Normet strengthened its position in underground construction and mining by acquiring 40 per cent of TAM International, a growing construction chemicals manufacturer and distributor.

News in brief

Chamoise upgrades

Bids are being accepted for lighting and road surface upgrades in the Chamoise tunnel on France's A40 autoroad. Tenders must be submitted to the contract authority, Society of Autoroads, by 12 August.

Eidsvoll electrotechnical bids

Electrotechnical work to turn the 1.2km two-lane Eidsvoll tunnel into two tunnels with one-way traffic is up for bid until 23 August. The tunnel, on E6 Boksrud-Minnesund, will have one part always trafficked during the work.

GEI hires for Midwest expansion

GEI Consultants has hired four senior professionals to help lead its Midwestern expansion efforts.

Ronald Palmieri, William Walton, Michael Gatzow and Michael Wheeler have each been elected vice president of the firm by GEI's board of directors. Palmieri has also been named GEI Midwest Regional Manager. In America's Midwest it has established offices in Chicago, Green Bay and Michigan's Upper Peninsula.

Crossrail tender

TENDER

Crossrail has invited contractors to bid for a contract covering the reconstruction of the Connaught Tunnel in East London. The project covers the Custom House to North Woolwich section on the GBP 15.9bn Crossrail project's southern spur and is expected to take four years to complete.

Work to be carried out under contract C315 includes construction of a new lining through a 105m stretch of the tunnel as well as repairing a stretch of Victorian brick arches running for 500m in the approaches to the tunnel. There will also be various surface railway works including improvements to drainage, footbridges and under-track crossings.

BB rebrand

TENDER

Bilfinger Berger Australia has been renamed Valermus. The move came ahead of a floatation, which is hoped will raise as much as AUD 1.3bn (USD 1.1bn) later this month when the offer concludes.

The Initial Public Offering (IPO) and the sale of Bilfinger Berger's entire shareholding in Valermus is expected to bring in AUD 780M (USD 657M) for the German company. The IPO will make Valermus the second largest construction and engineering group in Australia. Valemus chief executive Peter Brecht said, "European and Japanese groups dominated Australia's construction sector and the launch of an independently listed entity was an important development."

Tube extension rushes ahead

Left: The Northern Line extension is a vital part of the Battersea regeneration

GREAT BRITAIN

Initial responses to the public consultation for London's Northern Line tube extension to Battersea Park have been positive with almost all in favour of the project. Subject to approvals, the 3.1km extension could begin construction in summer 2012.

Early responses to the public consultation have tended to favour Route 2, which has an intermediate station at Nine Elms, south of the mainline railway tracks. Three of the four options have an intermediate station in the Nine Elms area. Route 1 has no intermediate station. The consultation began in late May and the closing date for responses was 28 June. A decision on the preferred route will be made by the end of the summer.

The GBP 500M (USD 756M) project is a vital transport connection for the Battersea redevelopment project by developer Treasury Holdings. The underground project is being entirely funded by the private sector using monies borrowed on future ticket sales, development levies and taxes.

Consultant Halcrow is working on the reference designs for the project. Halcrow's David McCann explained that the tunnels will be driven by two TBMs, from west to east. The TBMs will be stopped just short of the lines connection with the existing network at the Kennington loop. The machines will be dismantled and removed either via the Nine Elms Station or via a shaft at Battersea.

The contractor could opt for a one-TBM solution but it would be difficult to keep to the construction schedule McCann said. The contractor will have 12 months to excavator the TBM driven sections of the tunnel. McCann expects a flat average advance rate of 18m per day.

Immediately east of Battersea station is a crossover box. The combined space of these two excavations will give the contractor 100m to assemble the TBM for launch. Depending on the route chosen, driving east the alignment could be heavily congested with utilities. The drive will pass over or under, among others, EDF tunnels, the Thames Water ring main, main line rail, and the Victoria underground line.

The eastward bores do not run parallel as each of the possible alignments have been chosen to minimise the risk to surrounding buildings. As the bores reach the Kennington loop they split to connect on either side of it. A step plate junction will be used to link the Kennington loop with the extension. This section, which is some 90-100m, will be hand dug.

McCann said, "there has not been a step plate in London for some 15 years I think. But we learned how to do it once and we can learn how to do it again." The step plate is the only option that does not require closure of the Kennington loop, either temporarily or permanently. It will be completed with a series of weekend closures. The connection from end of the TBM driven tunnels to the Kennington loop will take approximately 16 months.

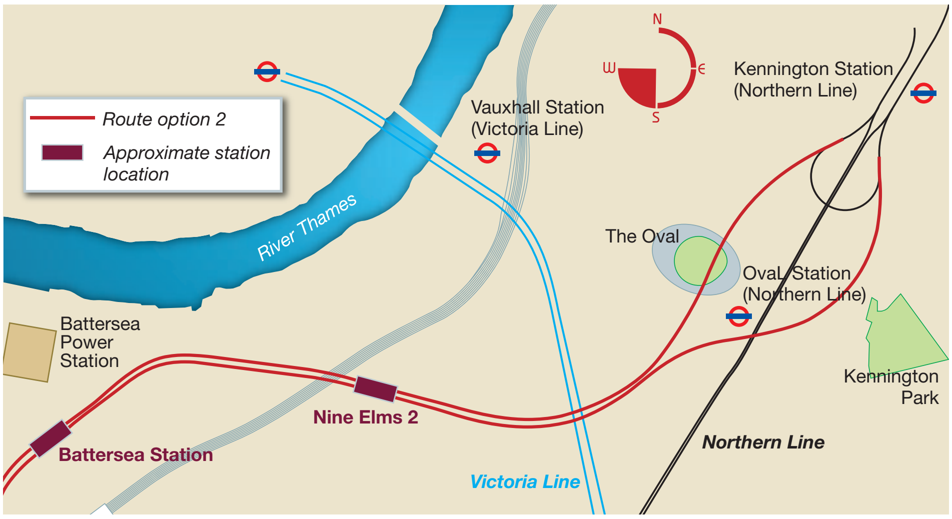
The muck from the tunnel will be taken out through an access shaft at Battersea and loaded on to a barge to be carried up the river. The tunnel is 28m below grade at its deepest point.

The project has a huge amount of momentum as it is pegged to this larger development. The developer is aware that forward movement on the Underground line will greatly aid the overall development's planning application, which is to be ruled on this autumn.

Tony Whitehead, project director for Treasury Holdings, said the project has the support of London Mayor Borris Johnson. Johnson earlier announced that the Nine Elms regeneration is the only development in London that is exempt from Crossrail levies, with the money going to the Northern Line Extension instead.

If all approvals are granted, the project is likely to be awarded as a design and build contract for the whole construction. The tender process will take 18 months and the contractor will be on site in summer 2012. The extension should open in 2016.

Jon Young



Right: The public consultation so far favours Route 2

© photo credits: VINCI and subsidiaries photo libraries

CONSTRUCTING A SUSTAINABLE FUTURE

At VINCI Construction Grands Projets, we engineer solutions that are not only financially competitive, but work sustainably for the planet. Superior design and construction practises are helping us save 20,000 tonnes of CO_2 emissions in two years. On the Hallandsas TBM project in Sweden, all the discharged water from the construction sites is monitored continuously quality and quantity wise before sent back to the natural environment. Also on this project, every chemical products used have been through a complete eco-toxicological evaluation regarding their impacts on human health and environment before being approved. Just one way in which VINCI Construction Grands Projets demonstrates sustainability leadership.

To learn more please visit **www.vinci-construction-projects.com/british-isles**

VINCI CONSTRUCTION | GRANDS PROJETS

Measuring up the Middle East

Metro schemes, roads and sewer projects are expected to boost to the tunnelling sector in the Middle East and North Africa with Egypt and the UAE leading the way reports Bernadette Redfern

The Middle East and North Africa are not typically hot beds of tunnelling activity. Apart from metro projects in Cairo and Dubai, attention is more often paid to the hand bored tunnels that Palestinians have dug under the Egypt/Gaza Strip border in order to smuggle in food and other goods. However the region is coming under closer scrutiny by the tunnelling community as regional governments invest billions of dollars in upgrading their infrastructure.

Much of this new focus is in the Gulf Cooperation Council (GCC) states particularly the UAE, Qatar and Saudi Arabia. "Twenty to 30 years ago it was impossible to think that Gulf States would ever embark upon tunnelling or metro schemes but under the new 2030 development plans regional governments are reclaiming the city and utilising the third dimension," says Martin Knights, chair of the International Tunnelling Association.

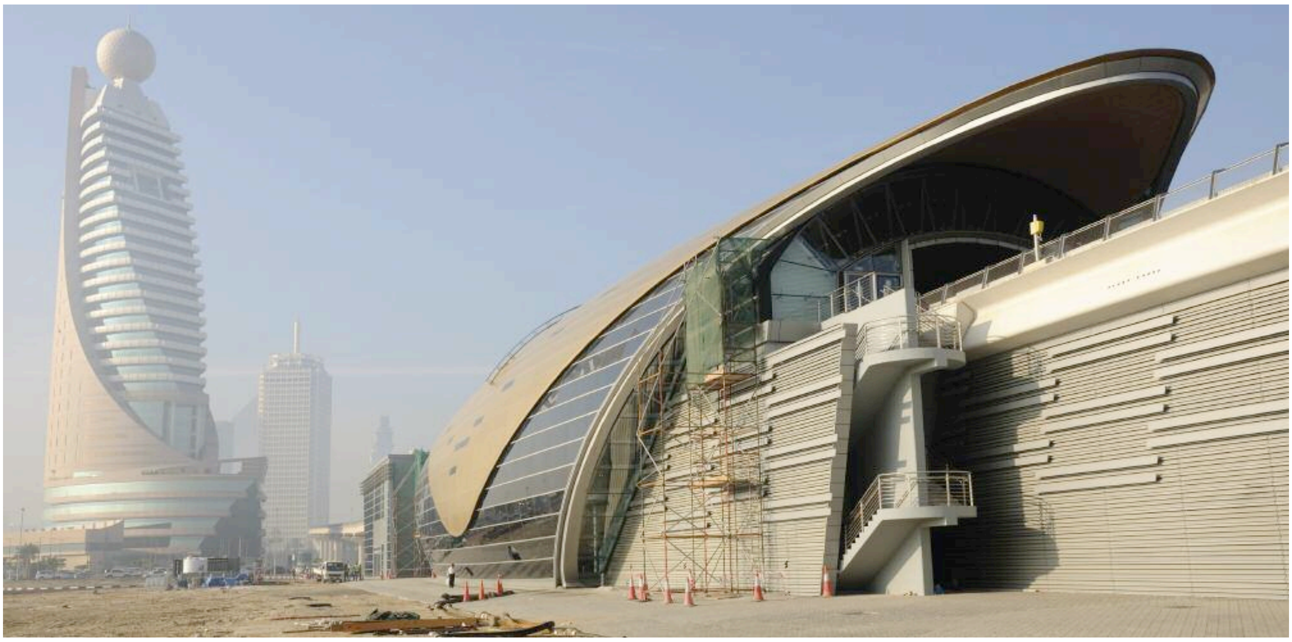
The most significant development in the Gulf's tunnelling sector to date has been the $7.6bn Dubai metro project which has involved significant tunnelled sections under the Dubai Creek. The first line, the 52km Red Line, was originally scheduled to open in September 2009 and cost $4.5bn. However although trains have been running since September 2009, eight of the 18 stations are still to be completed. The second 23km Green Line, has been delayed from March 2010 to August 2011. The contractor consortium is led by Japan's Obayashi Corporation, with Kajima Corporation, Mitsubishi Heavy Industries and Turkey's Yapi Merkezi.

Despite the cost and time overruns the project remains a major achievement for a part of the world with no previous experience of TBMs or light rail. Of the first 70km of light rail system, 13km were tunnelled using three 9.56m diameter Mitsubishi EPB-TBMs over 10 separate drives.

Plans for extensions of the metro are currently on hold as Dubai weathers the financial storm battering its state owned development companies and affecting governmental infrastructure spending, however Knights expects Dubai's metro will be extended in the future. Other states, he says, are also pursuing tunnels for metros, utilities and road links. "In the future I believe we are going to see the use of strategic tunnels linking islands in the region, instead of bridges and causeways."

Abu Dhabi, which neighbours Dubai and is one the capital of the seven states that make up the United Arab Emirates, has the most tunnelling potential with plans that include a metro of its own. The emirate's first bore, using a 6.3m diameter EPB - TMB is scheduled to launch in December as part of a 40km sewer tunnel known as the 'strategic tunnel enhancement programme' (STEP – see feature page 17)

This new collector is designed to replace the existing pumped wastewater network consisting of more than 50 pumping stations with a new gravity sewer system. A total of six contracts will be awarded for the scheme including three for the main sewer, two for the connection pipework and one for a new pumping station. To date Italy's Impregilo is the only company to have been awarded one of the



major contracts for the mid section of the tunnel in September 2009.

The main bore will run from Abu Dhabi Island in the north down to a pumping station at the new Al Wathba sewage treatment works on the mainland in the south. It concerns a 14.5km long section with a 5m internal diameter that makes up the central piece of the sewer. Contracts for the first section, a 17km stretch from Abu Dhabi Island to Mussafah on the mainland with a 4m internal diameter, and the final piece, a 10.5km section with a 5.5m internal diameter are being evaluated by Abu Dhabi's highest authority the Executive Council.

A total of eight EPBMs will be used on the bore to remove 1.2 million cubic metres of fill. So it is not surprising to hear that Germany's Herrenknecht is to establish a TBM manufacturing joint venture in Abu Dhabi with a local partner Aabar Investments. "We set up the new joint venture 'Herrenknecht Tunnel-Boring International LLC' together with Aabar Investments PJSC, a partner that is well networked and held in high esteem in the Middle East," says a Herreknecht spokesperson. "The business objective is the continuous market development of mechanized tunnelling in the MENA region (Middle East and Northern Africa)."

The German giant is already supplying a TBM to Qatar, which is increasing stormwater storage in the capital of Doha, and in Saudi Arabia it is supplying drilling equipment to Saudi Aramco for a new 3km oil pipeline.

"In total, we see the region as a growth market with promising perspectives such as ongoing and upcoming tunnel projects for metro and sewage systems," says the spokesperson.

In Abu Dhabi the information currently being collected on ground conditions for the sewer tunnel, which will be up to 100m deep, will be shared with the Department of Transport for the planned metro scheme. This is particularly critical in Abu Dhabi which is prone to large sub-surface voids. "Regional geological formations lend themselves to casting formations. These can be discrete or sometimes widely connected. You have to carry out very, ery good site investigation," says Knights. "And be mindful of your pump rates when grouting."

Just north of the UAE, Qatar has been following Abu Dhabi's sewer plans and in May invited pre-qualification bids from consultants to advise on creation of its own deep sewer tunnel. According to the bid invitation published by the Public Works Authority (Ashgal) the existing sewerage system, consisting of shallow sewers and pumping stations, is becoming overloaded due to the pace of development in the capital Doha. "A major tunnelled interceptor scheme is proposed in the Doha South sewage treatment works catchment to reduce the number of pumping stations and to meet the long term needs of Doha," says the document. "The existing Doha South STW will at some time in the future be relocated to a new site to the south and the existing site utilised as a treated sewage effluent (TSE) storage and distribution centre."

Above: **One of Dubai's recently built metro stations**

The scheme is expected to consist of five packages including the deep sewer tunnel, connecting sewers, a new pumping station and a new treatment works. The deadline for prequalification bids was the 1st June.

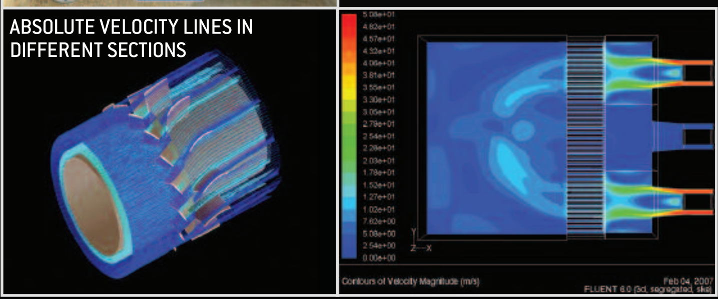
Further afield in the Middle East Damascus in Syria, Amman in Jordan, Kuwait City, Baghdad in Iraq, Tehran in Iran and Riyadh in Saudi Arabia are all planning metros and are keen to learn from pioneering Dubai's experiences – both good and bad. In North Africa, Egypt is extending its metro by adding a third line. A Vinci Construction Grand Projects led consortia is undertaking a 3.5km, 9.5 diameter bore under the River Nile. Construction is scheduled for completion in mid 2011 (see feature page 23).

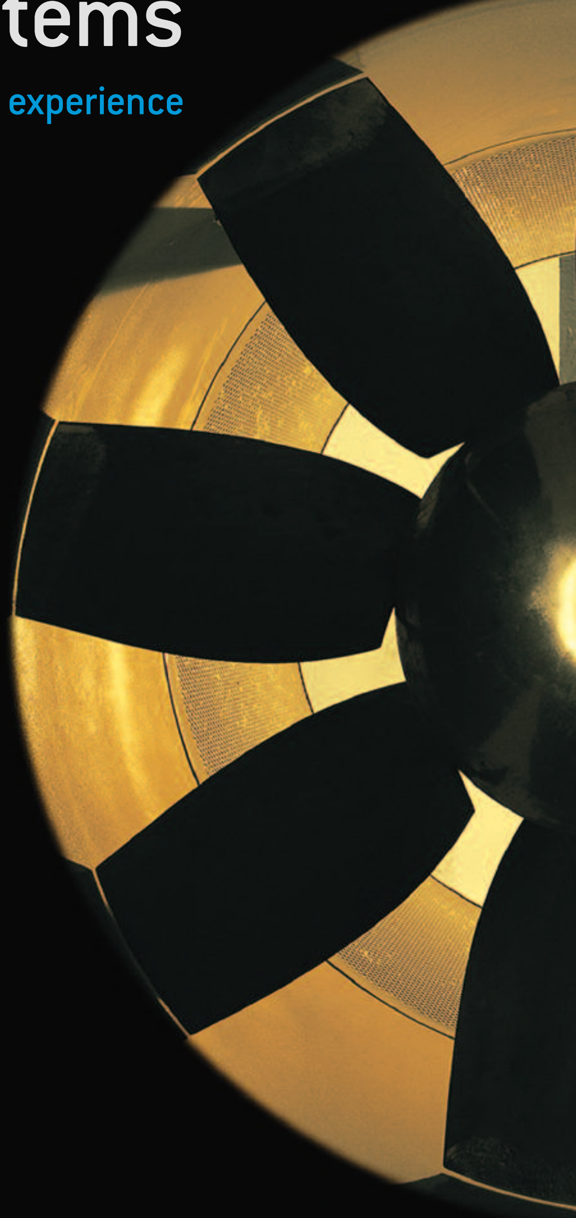
With so many projects planned and several underway it is no wonder that the industry is excited about the regional opportunity. However this is tempered with an air of caution as governments re-evaluate their growth forecasts after the global downturn. In Abu Dhabi for example the sewer tunnel contract awards have been delayed and the project pushed back to ensure that demand is adequate, and Dubai has suspended development of two new metro lines. But overall sentiment in the region is that a lot of major projects are going to get underway within the next five years. "Underground construction is going to increase in this part of the world like we have never seen before," says Knights.

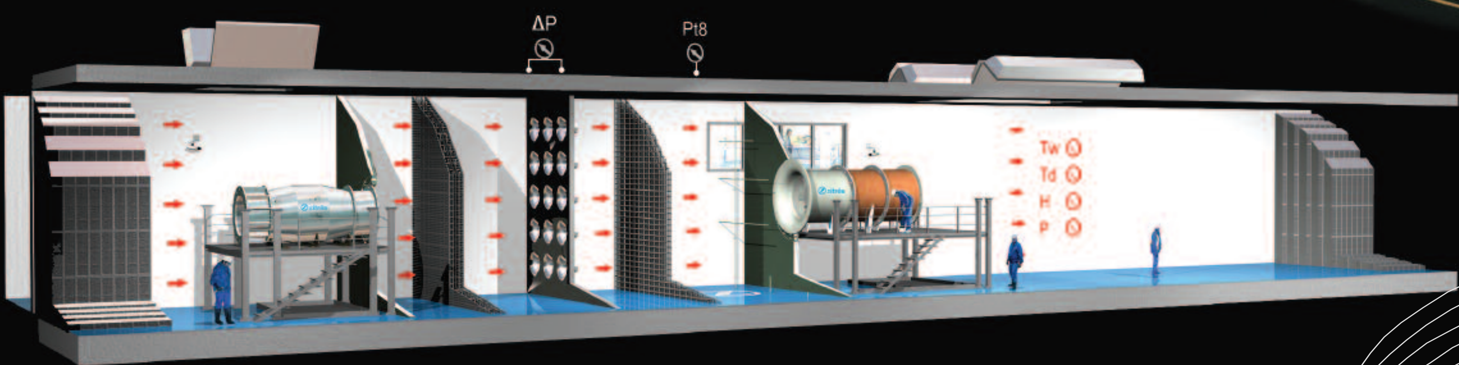
More than ventilation systems

The measure of our experience

Over 40 years of experience, a high degree of technological competence and highly qualified staff endorse our work which is among the most valued and acknowledged in our sector.







ZITRÓN, S.A.
Head Office: Autovía AS-II Nº 2386
33392 Porceyo. Gijón. Spain
P.O. box: 404 - 33280 - Gijón. Spain
Telephone: +34 98 516 81 32
Fax: +34 98 516 80 47
E-Mail: zitron@zitron.com

zitrón

Abu Dhabi's super sewer

Deep tunnelling will commence in the Middle Eastern emirate of Abu Dhabi for the first time later this year in a new 40km sewer project reports Bernadette Redfern

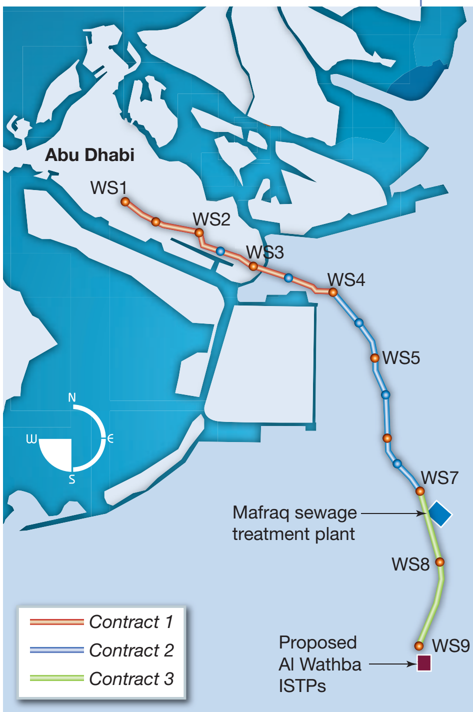
When the government of Abu Dhabi first installed a sewage collection system back in the 1970s it could not have predicted the stratospheric growth that was to characterise the next four decades. From a population of around 156,000 in 1975, it is today approaching 1 million and the network of 50 pumping stations and mains that collect sewage and transport it to Mafraq treatment works is severely under strain. The result has been some surcharging of the gravity mains that feed the pumping stations and not surprisingly this had led to complaints from the public.

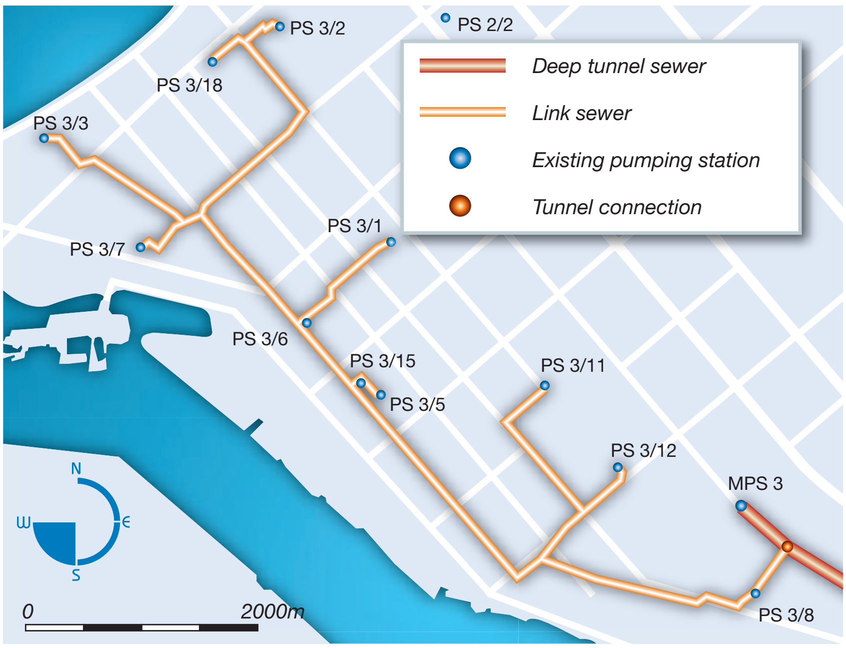
The organisation charged with managing and upgrading the sewer network is the Abu Dhabi Sewerage Services Company (ADSSC), formed in 2005, and until last year, a subsidiary of the Abu Dhabi Water and Electricity Authority (ADWEA).

Back in 2006 it undertook a masterplan which explored the potential issues that the emirate would face, along with proposing solutions for the network. "The original masterplan consultant GTZ Dornier called it a sewage time bomb," explains ADSSC managing director Alan Thomson. "It predicted that by 2009 Abu Dhabi would face mass sewer flooding. I am delighted to say we have managed to prevent this so far and we will continue to do so until the final solution is in place," he says.

Right: The 40km deep tunnel system has been divided into three contracts, one of which has been awarded

Below: A network of about 50 km of connecting sewers will feed into the main sewer tunnel

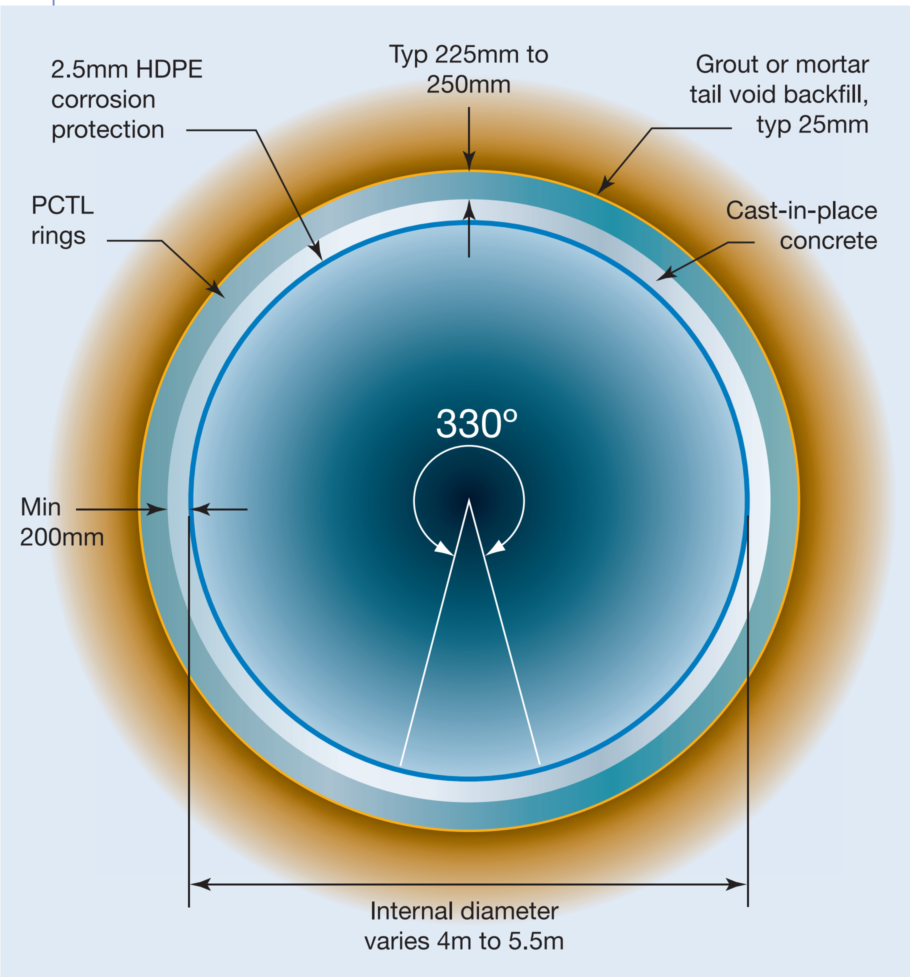




Masterplan

In 2007 the completed masterplan was re-visited following the release of the emirate wide growth strategy, "Plan 2030." This high level planning document set the strategic objectives for all government departments and, among other things, outlined expectations for a population of 3.1 million by 2030. A further separate independent check found the masterplan to meet all requirements for the new plan.

ADSSC's masterplan envisaged that to meet such growth the best solution would be a deep sewer tunnel that would collect effluent and transfer it all to a single pumping station by gravitation. This would then move flows to a new sewage treatment works at Al Wathba. As implementing something on this scale was



Above: **A typical section through the deep sewer tunnel**

beyond the experience of ADSSC, it decided to bring in a project management consultant to run the scheme. The winning bidder was announced as US based CH2MHill in February 2008. The firm was fresh from project managing Singapore's impressive 48km deep sewerage tunnel (DTS) project. "The first thing we did was revisit the feasibility study and look at the options," says Strategic Tunnel Enhancement Project (STEP) programme manager from CH2MHill Robert Marshall.

The first potential solution was the do nothing option, "to just keep the system going by patching it up but no major infrastructure," he says. The next option was to enhance the system by increasing the size of some of the existing pumping stations and refurbishing them where required, along with putting in new pumping mains with additional capacity.

The third option was an offshore pipeline as a conveyance route with a new treatment works. Option number four was the deep tunnel system. By comparing capital costs and operating expenditure the study came to the conclusion that over its 80 year design life the 40km deep tunnel was by far the most cost effective. "It also satisfied more of the qualitative issues," says Marshall.

So the team, which included members from ADSSC, pushed on with a concept design of the tunnel, which also required connecting sewers and a major pumping station to lift flows to the treatment works. "We looked at the tunnel route, what length it should be, where it should go, what diameter it should be, what gradient and what depth," says Marshall.

Starting on Abu Dhabi Island at 30m below ground level, the tunnel will run southwest to the mainland and terminate at a depth of 100m. Each bore will be 5km in length meaning that a total of eight EPBMs will be required, and the contract packages have been split into three. "We knew that breaking it into eight contracts would be too small for international contractors, so we broke it into three contracts, roughly around AED 750M to AED1bn each. These were large enough to attract international tunnelling contractors but not too large that you put all your eggs in one basket," says Marshall.

Design and build

As with many tunnelling schemes, the client opted for a design and build approach, and estimates that this saved 12 months on the construction programme as it allowed TBM orders to be placed at contract award, enabling detailed design and shaft sinking to be done in parallel with procurement of the boring machines. Designs were produced to approximately 30 per cent complete for the tender documents to be issued. There are three other contracts, two for connecting sewers and one for a pumping station, and to date all six contracts have been tendered and bid.

So far only one contract has been awarded. Italy's Impregilo picked up the AED 891 million (USD 246M), contact for the middle section of the sewer in September 2009. "This section has a 5m internal diameter and the three EPBMs will be 6.3m diameter. Testing of the first TBM will take place at the end of July," says Marshall.

The EPBMs are new machines coming from Herrenknecht's main facility at Schwanau in Germany. The first is scheduled to be installed in the launch shaft in mid-October with boring getting underway in December. The other two EPBMs are on a one month lag with testing taking place in August. Construction of this section is set for completion by June 2013.

Originally it was envisaged that the entire STEP programme would be completed by the end of 2012, however the Abu Dhabi government is carefully reviewing all of its growth forecasts in the light of the global financial crisis. The emirate has a reputation for conservative planning, a move that has served it well as neighbouring states have seen their growth plans plummet - along with bank lending.

As a result, although the remaining five contracts have been evaluated by ADSSC and a preferred bidder has been chosen, they are still awaiting approval from various government departments. "The more advanced contracts, which are the other two tunnel contracts, are lying with the highest Abu Dhabi authority the Executive Council," says ADSSC's Thomson. "The other contracts have been evaluated by our own team and are currently being considered by our chairman."

Given the current situation Thomson expects that 2014 is now a more realistic deadline for the project. "The other elements will be approved in due course. It is really just going through the bureaucratic procedures which are part and parcel of government controls," says Thomson.

Next expected to be awarded are the remaining two tunnel contracts. The first section is the 17km length from Abu Dhabi Island to Mussafah on the mainland and will have a 4m internal diameter. The final 10.5km section will run from Mafraq to the sewage treatment works at Al Wathba and has a 5.5m internal diameter. Access shafts will be constructed at 2.5m spacings and the winning contractors are expected to bore through the sandstone, mudstone and gypsum at rates of 100m per week.

Coping with the ground

The presence of gypsum presents a potential risk for the tunnellers. Its propensity to dissolve in the presence of groundwater has led to a series of underground voids and caverns on the mainland, which the team refers to as "solution features".

This risk led the contract team to specify pressurised face tunnelling for the bore to prevent any uncontrolled ground loss, and although ADSSC did not specify whether EPBMs or slurry, all contractors bid using EPBMs. "We also require the EPBMs to have the ability to forward probe and we have asked the contractors to provide forward looking radars to pick up any cavities. And we have compressed air so we can get into the cutterhead if there is a need to change tools," says Marshall.

Extensive site investigations have also been carried out with more investigation to be done prior to boring. "If a cavern was detected we would try and grout it up either from the tunnel or from the surface in advance of the TBM arriving. So far there is no real evidence of any solution features in the depths we are tunnelling in," he says.

From a tunnelling perspective ADSSC and CH2MHill are optimistic about the ground conditions as despite large pressures at the deepest point of the tunnel – 8bar, permeability of the ground is very low. "The biggest risk is encountering a very large cavern. The probability of this is low but the impact is high," says Marshall.

The EPBMs will place a 200mm thick concrete structural lining and once this is complete contractors will enter the tunnel with steel shuttering to place the internal lining that also acts as a dual corrosion protection system. This comprises HDPE that is in contact with the flows and a concrete backing cast in situ that is at least 200mm thick. "The structural lining is gasketed so it should be a dry tunnel. Any leakage that comes in from groundwater would find its way through the concrete and run down the back of the HDPE and run onto the tunnel invert as the bottom 30 degrees is not lined in HDPE," explains Marshall. "If it was fully lined then any water coming in would not be able to penetrate and so would bubble it until it burst, but ingress is expected to be very minimal," he says.

The HDPE itself will be supplied in 2.5m roles that will be welded together on the surface before running it into the tunnel and wrapping it around the steel shutters. The concrete liner will then be poured. This is a similar method to that used on Singapore's DTS. "In Singapore for example we had some shutters that were 37m long," says Marshall.

Above and next page: **Preparatory works underway at the launch shaft (WS5)**

In terms of a supplier for the shuttering this has not yet been decided. Impregilo's choice of firm however must be approved by ADSSC, a contract measure that is built in to protect the client. "We have written controls in place that are required to ensure that ADSSC get what they want in terms of durability, performance and protecting the general public. So for example we have specified that a new TBM is required that is designed specifically for the ground conditions," explains Marshall.

Connecting sewers

Also to be decided are the contractors for the two link sewer contracts that will feed

Left: The 6.3m diameter TBM is set to arrive and be installed at the launch shaft in October

flows in to the new sewer tunnel. Part of the rationale behind structuring the main tunnel and connection sewers in separate contracts is to enable both local and international firms to participate in the scheme and it is envisaged that local firms will be involved in link sewer construction. Between the the two link sewer contracts a network of 50km of connection pipes will be created. Marshall says these are not expected to be at risk of encountering solution features as the majority of them are on the island where such caverns have not been a problem.

Connection sewers range from 400mm to 3m diameter lying anywhere between 10m and 25m deep. These will be pipejacked in place from manholes at 3m centres and the biggest challenge for the team will be getting authority approvals for the detailed designs of the jacking pit locations and receiving pit locations.

The sixth contract to be awarded is for the new deep pumping station at Al Wathba sewage treatment works. "A single pumping station design was a major consideration in cutting down odour problems in the future as wherever you have a pumping station you effectively have sewage coming to the surface in one way or another and more likelihood of an odour problem," says Thomson.

ADSSC has reserved a 4.7ha plot of land from the Abu Dhabi Municipality for the pumping station and ground conditions are expected to consist of overburden soils followed by a weak sedimentary rock formation. Contractors will be expected to take into account expected artesian ground water conditions. According to ADSSC the construction of the pit could involve reinforced concrete diaphragm walls, secant pile wall, shotcrete and rock bolts, followed by inner structural concrete ring walls, intermediate slabs, and a base slab. However the most appropriate form of excavation support system will be left up to the contractor.

Although government is taking its time over awarding the contracts, the consensus seems to be that this piece of infrastructure is badly needed, and it is part of wider investment in the emirate's water network. "We are building another four waste water treatment plants, two in Abu Dhabi itself and two to cover Al Ain the second city. These are well in advance and will add an extra 800,000m3 per day to our treatment capabilities across the emirate," says Thomson.

Short-term measures

The current capacity at Mafraq is 360,000m3 per day but Abu Dhabi is currently averaging 500,000m3 per day. Fortunately for ADSSC the heat accelerates the bacterial activity that kills pathogens so although the wastewater is not being treated for as long as it was designed to be, the effluent leaving Mafraq is still high enough quality to be used for irrigation. As an interim arrangement ADSSC has placed connection pipes between the existing Mafraq sewage treatment works and the new treatment plants which will convey some waste water down to the new plants to relieve Mafraq. "Flows have increased 8 per cent per year. We are making temporary arrangements with overland pumping, tankering where that is practical, and a refurbishment of some of our pumping stations if only for a few years to improve efficiency to keep the wolves from the door," says Thomson.

Another advantage of the project is that it is also training local engineers to manage multi-billion UAE dirham capital projects – experience that is difficult to obtain in the region. "We have got people from ADSSC who are working on the project management and are from this part of the world that we hope that by the end of the project will have gained some valuable experience," says Marshall.

"This was very much a consideration at the start of the contract," says Thomson. "We discussed it before CH2MHill were appointed and decided that in conjunction with the ADWEA chair and board that is would be a valuable opportunity. At present we have five trainees. Once construction rolls out we would like to bring more in to the programme."

Much work remains to be done before Abu Dhabi's sewage problems are a thing of the past but major steps have been taken and a solution is on its way. The government is taking its time making the awards but at the same time is ensuring that Abu Dhabi gets the best infrastructure available. As a result the experience gained herein terms of both expertise and knowledge about local ground conditions, will be important information for other local and regional projects in the future.

Right: Robert Marshall, STEP programme manager from CH2MHill

One for two.

Herrengrosserstedt/Germany. As specialist in conveyor belt systems, H+E Logistik GmbH supplied the equipment required for the new construction of 2 tunnel tubes with a length of 7,000m each, which will accommodate a high speed train on the German railway route from Erfurt to Leipzig/Halle. This equipment guaranteed rapid tunnelling progress. The system includes two continuously extendable tunnel belts which are connected to a heap belt and operate a pivoting stacking system. This saves costs and maintenance work. Typical H+E.

The bare facts:

Tunnel diameter:	10.90m
Conveyor length:	2x 7,000m
Belt width:	1,000mm
Capacity:	2x 1,400 t/h
Installed power:	3x 250kW per tunnel
Belt storage capacity:	2x 500m/horizontal
TBM:	2x Hard Rock Shield
Installation:	2008
Contractor:	JV Finnetunnel

H+E LOGISTIK GMBH

H+E Logistik GmbH
Josef-Baumann-Straße 18
D-44805 Bochum
Germany
phone + 49 (0)234 | 950 23 60
fax + 49 (0)234 | 950 23 89
www.helogistik.de

Excavating Cairo's Metro Line 3

Cairo's rapidly growing population will have its transport problems eased by a new line for its metro system, reports Adrian Greeman

Parts of an EPB tunnel machine will be arriving at Marseilles docks on the French Mediterranean coast in July for loading and transport to Egypt. From there they will be moved to the capital Cairo and assembled in September for the second phase works on the city's third metro line.

The 9.4m outside diameter machine, from TBM maker NFM in France, will join a brand new Herrenknecht bentonite slurry TBM from Germany, arriving shortly before. The new Herrenknecht machine will be used to complete the first phase of the project, taking over from an existing 9.4m diameter Herrenknecht slurry machine, which is currently stuck in a section of now frozen ground, following a hole-through incident late last year.

This first Herrenknecht machine, christened Cleopatra, had already driven just under 4km on phase one of the new line when the suspected misplacing of two segments in the lining allowed an inflow of the water laden gravels and sands the TBM was passing through. With some 20m head of water this was a process that did not stop until the void had unravelled all the way to surface.

"Fortunately, no one was injured either at the surface or inside the tunnel itself," says project manager Jean-Pierre Dauban, for French contractor Vinci Construction Grand Projets. Vinci is lead contractor in a consortium building the tunnels for both the initial 5km plus phase one and a second stage that extends the work another 5km eastwards. Phase two overlaps phase one and was begun last year.

The alignment for the new tunnel is mostly along the centre of Cairo's relatively wide roads, and the hole-through during phase one happened under El Geish Avenue here—so there was no collapse or undermining of structures. Some damage to nearby buildings was sustained but otherwise the incident has caused problems primarily for the contract team, flooding the last section of the existing tunnel and drowning the machine itself.

"The situation on the surface has been rapidly controlled and came back to normal within a few days for the people living around, with the exception of the traffic on the avenue which was stopped to repair the sinkhole," says Dauban.

"But to overcome the problem we were obliged to flood the tunnel with water including the TBM machine after having built a wall some hundred meters behind the back up. This was necessary to stabilise the water pressure in the ground and avoid further collapses," he explains.

Since the cut-off wall was created, the area around the machine has been made watertight with a ground freezing operation, he says, carried out by subcontractor Bauer. The freeze, along the machine and 25m of tunnel beyond, allows the construction of a shaft in front of the cutterhead from which it will be possible to access the machine and dismantle it to take it away for repair.

He hopes this can be achieved by the end of this year. The shaft is already complete and clean-up and repair of the tunnel itself is underway.

Despite the incident and the complex ongoing rescue operation, which has cost the project some 11 months on its already tight schedule, Dauban is still optimistic

Above: **Cairo's metro system is the 15th businest in the world, but the streets are still jammed** that the first section can be completed on time. The new machine should be able to start a drive from the far end in August completing the outstanding 1,200m by the year's end, with E&M and signalling to follow in short order. "We have adopted some acceleration measures for those," he says.

Meeting demand

Opening of the line is on a very tight schedule, due in October next year, which is politically an important moment in the country when the president, Hosni Mubarak, finishes a term in office. Completion will have an immediate impact on the city. Line 3 is much needed as a complement to the existing two lines built in the last two decades, both by Vinci or rather its predecessor companies.

The two original lines run north-south, more or less along the Nile riverside, and the system is already counted as the 15th busiest in the world, with more than 700 million passenger rides annually. But even that makes little impact on the traffic that jams the streets; anyone who has visited the city in the past few years will know that even simply crossing the road is a hair-raising business of threading through a never-ending stream of cars.

It can only get worse. Cairo is one of the fastest growing cities in the world, a mega-metropolis with a population of 6.8 million in the city proper and another 10 million in suburban areas and possibly already much more than that, as a constant inflow from the countryside expands it. Cairo's population is also one of densest in the world.

Line 3 will cut across the city, east to west, eventually making a connection as far out as the city's airport on one side. On the other side it will join up important suburbs in a Y-shaped route with branches heading north and south at that end.

The two current phases under construction will be the busiest sections, serving the centre parts of the city. Phase one runs from Attaba near the Nile where the line will connect to the existing Line 2 in a deep, multilevel station, and heads east for 5km towards the airport. It includes five stations. Phase two takes this onwards another 6.5km with another four stations.

Phase three will extend the Attaba end across underneath the Nile river and is itself split into three sections, a 5km long stem of the "Y" and the two branches of 6km and 7km, the main one heading down close to Giza. Design for these sections is underway but tunnelling is not due to start until 2011.

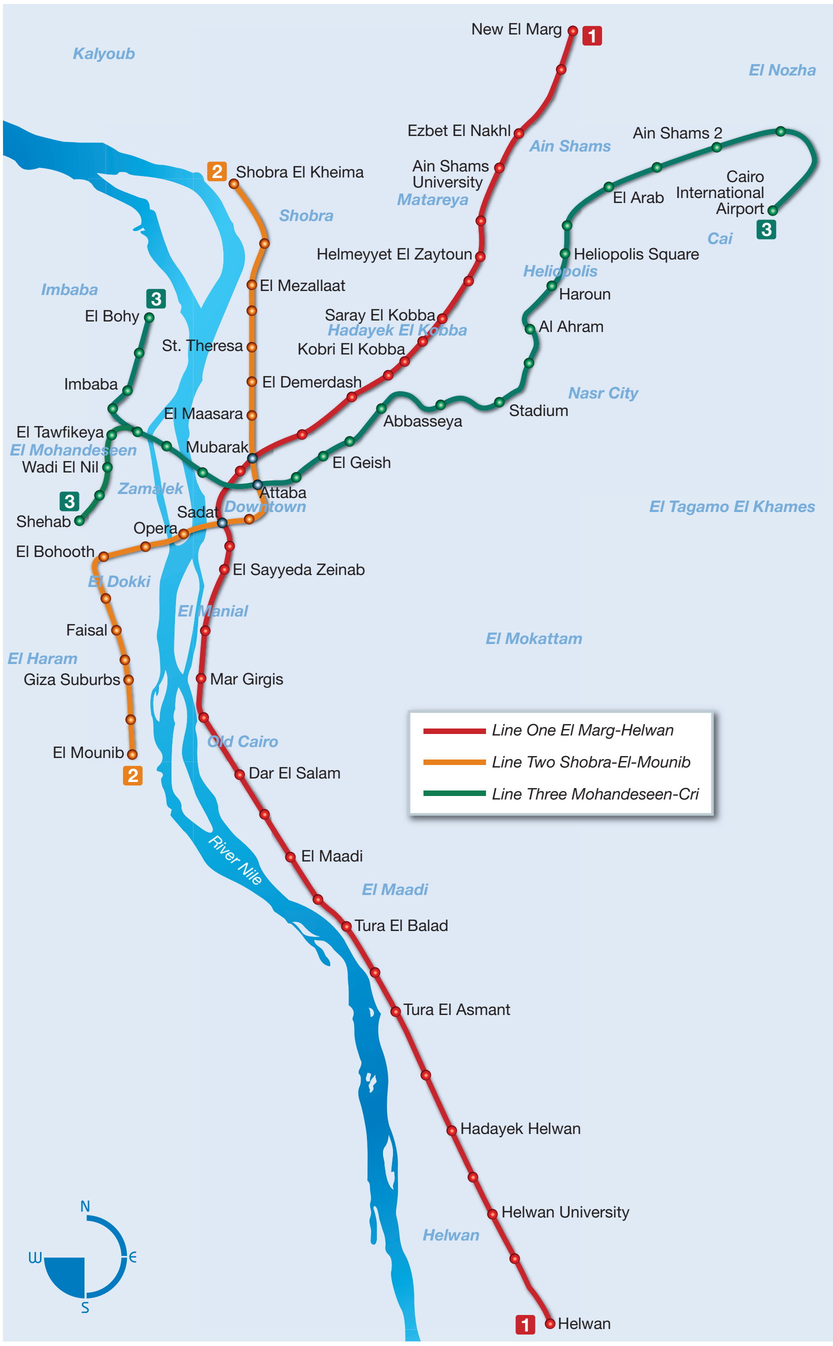
A final phase four will finish the connection towards the airport with another 11km of tunnel and seven stations.

The latter two phases are not yet let, though Vinci is hopeful of getting them, not least because there is a significant tranche of French foreign aid money involved in each of the project stages. A negotiated agreement was made at the time of the first award that it should get the second stage as long as the cost arrangements did not increase over the first phase.

Cutting Line 3

Vinci is lead contractor with 28.5 per cent of the project in a full consortium with three other partners; Arab Contractors, Bouyges, and Orascom. Initial design of the route is by French transport specialist Systra, producing a part detailed design with full engineering design by the contractor group itself.

The group was also well placed to win



Right: **Existing Lines 1 and 2, and Line 3, which will be built in four phases with completion scheduled for October 2011**

Above: **A standard segment pattern has been used for the tunnel**

the initial EUR 226M (USD 283M) contract after making significant experiences in Cairo on the first two metro lines. The TBM Vinci had been using on the first phase until the hole-through was one of the original two machines used on those lines.

"The machine had been in France where it was reconditioned," says Dauban "and then brought back."

Work on the project was let by client the National Authority for Tunnels, part of the Ministry of Transport, in April 2007 to start in July with tunnelling beginning the next year. A three-month train test period was to be part of the 48-month schedule.

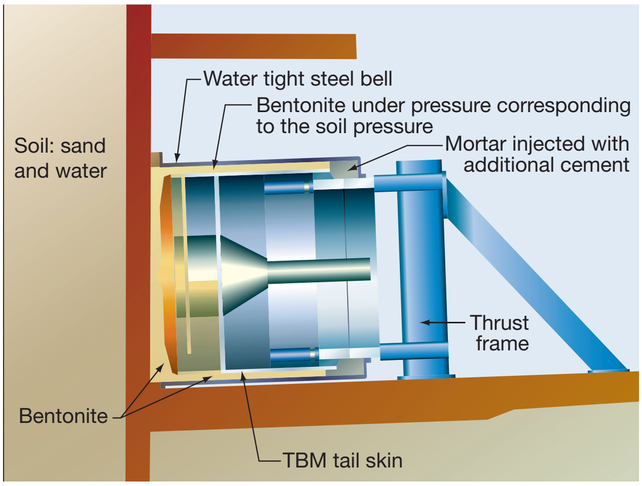
Despite the problem at El Geish, the tunnelling is relatively straightforward says Dauban. The machine drive began from an entry shaft just beyond the fifth Abbasia station at the airport end of the section heading back and made good progress, averaging some 12m a day but with peaks of 20m plus achieved.

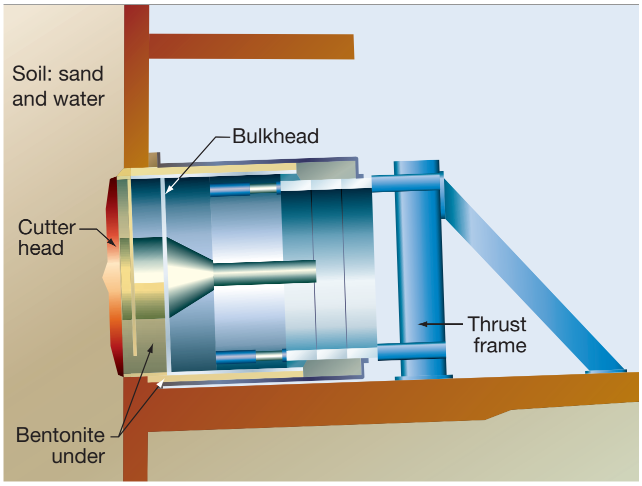
It goes entirely through Nile river bed deposits, with a high water table creating a head of pressure between 20-30m, conditions
most appropriate for a slurry machine.

Spoil is recovered from the used slurry at a single separation plant about halfway along the route.

The difficulties of working in Cairo emerge at this point, because the spoil must be stored during the day for removal

Right: **The tunnel lining stops at Abbasia Station and the TBM is winched through**





Above and Right: **Figures 1 and 2 — A bell-shaped, steel casing has a double-layered skin with a bentonite fill that provides a flexible seal**

only at night when the traffic levels drop to some extent. Subcontracts with local companies see to the removal and disposal of spoil, the later of which is not a great problem once you are 40km from the city in the surrounding desert.

Permanent support

A standard segment pattern is used for the tunnel, with seven main segments and a key. Each is 1.5m long, 200mm thick and weighs 5.7t, and the ring is grouted from the tail of the machine with a conventional cement grout, producing an 8.4m internal diameter tunnel.

The total 22,400 segments are made at a precast plant in the suburbs by a subcontractor, Bona Pipes, which is one of Cairo's biggest concrete pipe manufacturers. The company also did the segments on the Line 2 project.

"We supplied the moulds, and other equipment and they poured the concrete," says Baudan. "We were able to re-use four mould sets from the previous project though there is also one new one, and we have added another two for the second phase work."

Again, delivery to site has to be at night.

Permitting for street possessions and deliveries has also been a significant part of the work on the stations says Dauban.

These have been made using full possessions of the streets, rather than in the logistically more complex half side occupations, but that has meant complicated traffic diversions and arrangement have been needed.

The stations are 150m long boxes, mostly with two levels inside for concourse and platforms, and in most cases about 30m deep.

"The last station at Attaba is deeper, about 50m, and has five levels," he says. "This is the interchange with Line 2."

Stations are built beginning with diaphragm walls to about 40m depth. Specialist Bauer has done most of these using hydrofraise type machines though for the deeper walls at Attaba, which go all the way down to underlying clay layers for watertightness, the consortium used Intrafor/Bachey because it was the only one with machines available for reaching up to 100m depth, as required.

One the walls are in place, a base seal is created by grouting and then top down construction has been used. The intermediate floor slabs, made on the way down, provide structural support for the next section. Concrete arrives from one of three batching plants set up to ensure the deliveries never have to travel more than 1.5km. Arascom, Egypt's main cement supplier and now part of Lafarge, operates the plants.

"The lowest slab in the stations is not made until the TBM passes, however," says Dauban, "and so we have to use steel tubular strutting at the bottom." The TBM reaches each station after excavation and is pushed by hydraulic rams across the intervening space on rails.

Steel bell

To get the TBM into the station space Vinci has devised an intriguing steel bell system. "Normally you would have to grout a watertight block in the ground outside the diaphragm wall to avoid leakage problems at the boundary," Dauban explains.

Instead, a special bell shaped steel casing is set up, attached to the diaphragm wall on the inside. It has a double layered skin with a bentonite fill inside to provide a flexible seal (see Figures 1 and 2).

Inside this the TBM begins its forward progress, assembling and grouting its segment rings as it passes through the 1.2m thick concrete wall, so that a tunnel junction is formed "automatically." The wall has no special "eye," just the normal concrete, Dauban explains.

"We used the 'cloche' first for an exit of the machine but now are also using it for entry into the box as well," he says. "It is less costly than a full grouting of the ground."

Until the TBM hole-through, progress on this machine was good. Dauban is hopeful that it will go well with the new Herrenknecht machine, which is to the same specification as the older one,"but with modern technology."

Later phases

Meanwhile attention is turned also to the second phase works, which were let last year. An initial drive of nearly 2km for this will be made using the new Herrenknecht that will have to be brought from the first phase tunnel once it has completed. But further eastwards the geology changes as the river deposits give way to the river valley base rock and the desert beyond, a mixture of mudstones and sandstones.

To make this drive the consortium will use the EPB from NFM, which is just finishing its test trials at NFM's works in France. "The rock is not too hard," says Dauban.

Mucking out will use a rail mounted system with two separate trains made of seven mucking cars each, which can be moved in parallel inside the tunnel and inside the TBM back-up.

The phase four section of the route, which should begin in 2012, would also run through this kind of rock.

Clarifying the fog of fibres

In response to reported confusion over the roles of fibres in concrete and, in particular, the claims and counter-claims of suppliers of steel and synthetic (polymer) versions, concerning their advantages and disadvantages, Tunnels & Tunnelling International has decided to try to clarify the issues involved for our readers. Maurice Jones reviews the responses to an information gathering questionnaire and other relevant evidence so that readers can, perhaps, make their own judgements

The gathering of opinions and evidence was commenced with the issue of the independently verified questionnaire sent out to both specifiers and suppliers covering those fibre properties most often quoted as advantages or disadvantages of the two main types. This asked for opinions of which properties were relevant, advantageous or disadvantageous, for each in the applications of sprayed concrete, pre-cast lining segments, and cast in situ linings. Respondents were also invited to expand on the views with more reasoning and to provide any supporting evidence in the form of relevant testing or national and international standards met.

Below: **A mine tunnel supported throughout by arches and fibre-reinforced sprayed concrete [Photo: BASF Meyco**

Important properties

Supplier respondents to the questionnaire usually indicated that major properties were important whatever the type of fibre, albeit perhaps from different perspectives resulting in major differences of opinion. Promotors of steel fibres questioned the design life of synthetic fibres, maintaining that this is not proven, and the validity of the values of Young's Modulus of Elasticity (E) for the synthetic fibres. The latter is applicable to stretching of the fibre or to the bending of a (test) beam and is defined as the ratio of stress (tensile or compressive) over strain (tensile or compressive). Steel fibre proponents draw attention to the different Young's Modulus values for concrete (around 30GPa), steel (200GPa) and synthetic fibres (about 9GPa). However Andrew Ridout of ElastoPlastic Concrete (EPC) says, "The Young's Modulus is not an issue with fibre-reinforced concrete as this is a composite material. As such it is the performance of all the components working together to produce a performance that is of interest."

Environmental

On the hazards that fibres may face once in place, both camps maintain that the other is not effective (alone) in a tunnel fire. In the case of macrosynthetic fibres it is claimed by steel fibre producers that when they melt in the high temperatures, all reinforcement effect is lost. On the other hand, the beneficial effect of (non-reinforcing) microsynthetic fibres is widely accepted in that their melting creates microscopic passages for the release of vapour build-up in the heated concrete, thus deterring spalling damage. Therefore they are recommended for use whatever the type of reinforcement. For their part, synthetic fibre producers claim that steel fibres can actually aggravate the spalling problem through heat transmission and expansion, whereas macrosynthetic forms have similar effects to microsynthetics.

It is in the long-term (time-dependent) properties of the fibres in situ that there are major disagreements, leading to them being the subject of several programmes of research. One such property is corrosion. It is well known that synthetic (polymer) fibres are resistant to most acid or alkaline environments. Synthetic fibre producers cite rusting or other corrosion of normal steel fibres as a problem, but (see below) steel fibre producers deny this except for aesthetic reasons, and state that galvanised fibres are available if required.

Benot de Rivaz of Bekaert says, "steel fibres need only a concrete cover of 1-2mm compared to 30-40mm for normal rebar and mesh. Corrosion of the (steel) fibres may cause discoloration but does not affect the mechanical properties of reinforced structures. Brite Euram (see reference) shows that fibres in crack openings smaller than 0.25mm do not corrode."

To counter this, EPC cites work on subsea tunnels, particularly in Norway, showing corrosion of steel fibres. According to Ridout (see reference code), the Norwegain Public Roads Authority has carried out a lot of work on the subject and has concluded that steel fibre should not be used in subsea tunnels.

Another example of long-term performance is that steel fibre producers maintain that macrosynthetic fibres will 'creep' over cracks in concrete, effectively losing most of their reinforcement/loading effect. This applies to both short-term and long-term ground movements that may distort the lining.

Design life

Macrosythetic fibres have a disadvantage in that their track record is not so extensive as that of steel fibre reinforcement due to their later introduction and the lack of meeting international standards so far. Proponents are sure that this problem will be corrected soon and, say that in any case, is made irrelevant by project-specific performance testing. This difference applies mainly to sprayed concrete. In the case of pre-cast segmental lining, the difference is not so pronounced with steel fibre producers still working on the replacement of more and more conventional rebar reinforcement. Where fibres are accepted, only partial replacement of the bar reinforcement cage is the norm, although there are some cases of total replacement by steel fibres. Apart from cost-saving, the main advantage is prevention of damage during fresh segment handling as most in situ forces are in compression.

Bekaert's de Rivaz points out that design methods are only validated for steel fibre so far (see Rilem reference). For the macrosythetic fibres the claim to longer design life is based mainly on corrosion resistance. Ridout states that the fibre only starts to work when the concrete cracks, before which it does very little in terms of structural capacity. He says, "any crack will possibly allow moisture to come into contact with fibre reinforcement. The degree of degradation of the fibre will be dependent on the crack width, the concrete's environment and fibre type. Using synthetic fibre will substantially improve the structure's design life particularly in aggressive environments."

Tensile strength

The tensile strength of the fibre, especially across a crack, is sometimes cited as another factor in favour of steel fibre. However, Ridout states, "the tensile strength of individual fibres is not relevant as we are dealing with a composite material that needs to attain a performance in either a plate or beam test. The performance in the test is determined by how much ductility is produced from the composite and this is determined by the bond/pull-out of the fibre in the concrete. From a quality perspective, macrosynthetic fibres should have a minimum tensile strength of 500MPa, which ensures that high quality materials are used to manufacture the fibre, and for steel fibres a minimum of 1,100MPa."

De Rivaz says that fibre tensile strength should be matched to the concrete mix formula and its compressive strength, with a 'non-brittle' criterion.

Anchors and bonds

The efficiency of fibre performance in situ depends on adequate anchorage in or bonding with the cured concrete mix. For example smooth fibres of any type would present problems such as inadequate structural use. The Bekaert Dramix and HIC type of fibres offer hooks at each end for anchorage while most of the fibre is friction free. EPC BarChip macrosynthetic fibres are embossed along the full length. Advantages are claimed for both but in any case pull-out tests can determine the efficiency of any fibres in this regard, as well as by the usual beam or plate test of the concrete.

EPC's Ridout points out, "the principle is not for the fibre to be bonded so much that it snaps, but to pull out from the concrete to provide ductility. This is a combination of getting the fibre length, thickness and anchorage optimised to provide the best ductility."

The finer the fibre per unit weight, the more fibres will cross a crack, according to Ridout. However fineness also means that the fibres can snap more easily, and can cause mixing problems. Therefore a balance has to be struck.

Fibre length

Related to bonding is the fibre length. In theory the fibre should be as long as possible, but the length is usually determined by dosing and mixing performance. Bekaert says that the fibre length should be three times longer than the biggest aggregate particle to ensure anchorage. EPC claims that steel fibre length is limited by the size of the concrete spray nozzle whereas macrosynthetic fibres are not.

Creep

One of the most controversial alleged features of macrosytehtic fibres is the phenomenon of creep, or the lengthening of fibres over a crack beyond its load-bearing limit.

In structurally cracked linings, such as in asymetrically moving ground, this may not be an issue at all.

One of our questionnaire referees (subsequently known as Referee C), who wishes to remain anonymous due to promixity to a major project currently in design, pointed out, "in civil engineering we don't normally expect tunnel linings to work that hard, especially if the loading is uniform. Asymmetrical forces could, however, give higher bending moments that can produce serious crack problems."

Embrittlement?

Another aspect of long-term performance is embrittlement (of steel fibres). De Rivaz of Bekaert says that this is a totally incorrect concept and not a design problem, and produces an expert critical analysis to back up this claim. However, this has not deterred various research bodies from including the subject in studies on long-term, fibre-reinforced concrete behaviour. According to de Rivaz the toughness of the fibre and concrete mix, plus its post-crack residual strength are much more important to consider.

Cost

A possible error in drawing up our original questionnaire is that it did not distinguish between the temporary

(primary) support use of fibre-reinforced sprayed concrete, and its use as permanent (final) lining. This obviously determines the desirability of properties affecting the longer term efficiency of the fibres. Also, depending on who decides the composition of temporary support mixes, cost of fibres may become more important. Contractors left to determine temporary support (not eventually forming part of the designed final support) will naturally go for cheaper materials if they are effective over the time period required and acceptable on health and safety grounds. In moving ground the choice of fibre may be critical.

The costs of fibres are greatly affected by market forces and alternative supplies. The effect on the design of permanent lining is minimal compared to the potential savings compared to traditional reinforcement and the importance of a robust design. In sprayed primary lining, the contractor generally has to meet a test performance specified by the designer. It is then the contractor's choice how to meet this, and that is generally a question of balance between cost and quality, necessitating a higher dosage of lower cost/lower quality fibres to meet performance requirements. There are supplies of cheaper fibres available from Asia, normally China, both of steel and polymer materials, but these should be assessed on the basis of quality as well as costs as all fibres are far from the same, even when ignoring likely lack of technical support.

Bekaert's de Rivaz comments, "the cost per cubic metre should be for a clear, given performance, and technical requirements should be evaluated project by project."

Ridout agrees that cost is dependent on the quality of the fibres being compared. "Generally a comparison of the top end of the market for steel fibres and synthetic fibres shows a possible saving of about five per cent by using macrosynthetic fibre." However, he comments that steel prices have been very volatile of late whereas polymer pricing offers more stability even with fluctuations in oil stock prices. "In 2008 there was a lot of pressure on steel prices," he says, "as China took up most of the iron supply and this is threatening to happen again. This will make macrosynthetic fibres more costs effective." He claims that the A3 Hindhead Tunnel had to change to macrosysthetic fibre as no steel was available at the time.

Density & handling

The low density of synthetic fibres is often quoted as a factor in easier materials handling and safety, but with the correct equipment, any fibre handling should not be a problem. Bekaert emphasises the use of correct dosing equipment.

Ridout points out that CE marking of fibres shows the amount of kilos of fibre required to meet the CE specification; a ratio of 1kg of macrosynthetic to 5kg equivalent of steel fibre is stated. Although macrosynthetic fibres are lighter than water, and so will float, Ridout says that they do not float on the concrete mix as they are held by the cement and aggregates in the mix, that are able to hold the fibre homogeneously.

Packaging can be important in correct handling and mixing as, for example, Bekaert Dramix fibres are glued together in line for easy dispersal in the mixing as the glue dissolves.

Puncture hazard

Another alleged hazard of steel fibre reinforcement raised by synthetic fibre producers is that of puncturing, whether of workers or materials. From the point of view of tunnel construction this has to be addressed when using waterproofing membranes, but steel fibre producers point out that this is not a problem when a fleece/geotextile layer is employed between the membrane and shotcreted rock surface, as is usually the case.

A puncturing/scratching hazard of steel fibre has been accepted by many mining operations now using synthetic fibre reinforced sprayed concrete, although the circumstances of mining are usually a bit different to 'civils' tunnelling.

The possibility of a puncture hazard from fibres is non-existent from macrosynthetic fibres but, according to Bekaert, restricted to only fibre of diameter less than 0.2mm as used in Ultra-High-Performance Fibre-Reinforced Concrete (UHPFRC) otherwise known as bomb-blast concrete. EPC claims that experience in Australian mining shows that steel fibres can cause short-circuits in trailing cables and tyre punctures. Alleged damage to waterproofing membranes and operators seem to be less of an issue.

Further studies

Indicative of the less than clear current information on reinforced concrete mix design is the high level of current and likely future studies being undertaken.

Above: **Forming pre-cast segments using EPC BarChip macrosynthetic fibre-reinforced concrete for a tunnel in Malaga, Spain**

The continued activity of ITA Working Group 12 (Shotcrete Use) announced, under new animateur Atsumu Itshida of Denei Kagaku Kogyo Co of Japan, a test programme for evaluation of fibre-reinforced sprayed concrete, and discussion and information collection on mix design and durability to compare the durability of sprayed concrete and cast concrete. There has been agreement on the concrete mix and testing programme for short-duration loading, but long duration load tests were still under discussion.

Prof Dr Tarciscio Celestino at the Sao Carlos Engineering School of the University of Sao Paulo (see below) is conducting research into shotcrete for temporary and final linings focussing on time-dependent behaviour of both the rock mass and shotcrete, toughness of fibre-reinforced shotcrete, and the use of acoustic emission to identify the interaction between fibres an shotcrete.

The International Tunneling Consortium at the University of Texas, under the direction of Dr Fulvio Tonon, is conducting research into fibres for final linings and shotcrete, including time-dependent behaviour such as creep tests on structural synthetic fibres—both single fibres and bending creep—in beams. Embrittlement over time of steel fibres and quantifying of loss of reinforcing strength caused by concrete strengthening are also covered. Other work covers the interaction between normal stress and shear resistance, further work on validation of algorithms developed for the normal force bending moment interaction diagram for steel, synthetic and fibre blends, and a review of the ASTM 1550 text ('pizza test') and the use of ASTM C 1609 on portions of rectangular panels to provide design input.

In Norway the COIN study conducted by NTNU covers many types of performance improvement in concrete including the use of fibre reinforcement. One aspect is the use of glass-fibre or carbon-fibre reinforcement to avoid steel corrosion. Plus more efficient, less-expensive solutions to correct mixing of fibres into the concrete.

Referee C commented that there is better research and development on synthetic fibres year on year, thus improving its performance knowledge position. On both counts specifiers have to keep up to date with the latest findings to ensure that correct choices are made. The importance of performance-related testing was emphasised.

Applicable performance

If possible testing should relate to the conditions of the tunnel application. Therefore it is necessary to determine not only the performance of the fibre within a selected concrete mix, as in the various standard panel and beam testing methods, but also the performance of the concrete under in situ conditions, as near as can be simulated.

Performance-related specifications are therefore preferred except for very commonplace tunnel conditions, if such things exist. There are accepted tests of panel or beam samples of the concrete mixes that can assess correct 'manufacture.' However, for permanent (final) lining these designers also need to take into consideration the long-term conditions such as possible changes in ground loading, corrosion and alleged embrittlement.

For excavations subject to strong ground movements the extra considerations may be for the relatively short term as well as long term.

Most agree that it is a great challenge for designers and other interested parties, including suppliers, to demonstrate how the various mixes of fibre-reinforced (especially sprayed) concrete will work in situ, except perhaps in full-scale trials. Even then long-term performance involving cracking and ground movement (if any) may not be clear.

Conclusion

It is not the place of the author to decide for you which type of reinforcement fibre is the correct one for you, for your application. There is a great variety of tunnel support requirements, so therefore generalised testing seems to have limited relevance if tunnelling conditions are not clear.

As above, while total simulation of materials performance under tunnel conditions is extremely difficult, the correct fibre and concrete mix choice has to be based on a complete understanding of the concrete's in situ performance.

Acknowledgements

We wish to thank the referees that reviewed our original questionnaire, suggested amendments and additional questions, and provided additional information. These included Prof Tarcisio Celestino manager of civil engineering at Themag Engenharia, Sao Paulo, Brazil, and immediate past animateur of the ITA Working Group 12: Shotcrete Use; and Prof Fulvio Tonon of the University of Texas, Austin, US who is leading a research programme on reinforced sprayed concrete under the auspices of the International Tunneling Consortium, based there.

Some relevant Standards and references

ASTM International. Standard specification for steel fibers for fiber-reinforced concrete. Standard A 820/A 820M-06

Barnard, E S. Embrittlement of fiber-reinforced shotcrete. *Shotcrete,* Summer 2008 pp16-21. American Shotcrete Association.

BRITE EURAM studies. New materials, design and construction techniques for underground structures in soft rock and clay media, BRE-CT92-0231 Final Technical Report, Mott MacDonald Ltd, 1998.

BTS Specification for Tunnelling 3rd edition, 2010 Thomas Telford, London

Concrete Society (UK) & Clarke, J. Report TR63 Guidance for the design of steel-fibre reinforced concrete. March 2007. The Concrete Society. See also TR 65(2) for macrosynthetic fibre concrete.

Hagelia P & Norwegian Tunnelling Society. Publication No.17 – Underground Openings – Operations, Maintenance and Repair. Chap 12: Deterioration mechanism and durablity of sprayed concrete in Norwegian tunnels. (2008)

EFNARC plate test – similar to RDP using square panels and with a known relationship in performance reading between the two

EFNARC European specificaion for sprayed concrete – Guidelines for specifiers and contractors 1999

European Standard BS EN 14488-3:2006 – Testing sprayed concrete. Flexural strengths (first peak, ultimate and residual) of fibre reinforced beam specimens

European Standard EN 14889 – Part I (Standard for steel fibre quality)

European Standard EN 14889 – Part II (Standard for synthetic polymer fibre)

ITA – International Tunnelling Association Working Group No.12 Shotcrete Use. 'Report from the Working Group' 2006

Papworth, F. Design guidelines for the use of fiber-reinforce shotcrete for ground support. *Shotcrete.* American Shorcrete Assoc. Spring 2002

Round Determinate Panel (RDP) test or American Standard ASTM C-1550 Round Panel Test

RILEM TC 162-TDF. Final recommendation: Test and design methods for steel fibre reinforced concrete sigma-epsilon-design method. RILEM Publications SARL, Bagneux, France, 2003

Swannel, N G. Fibre-reinforced sprayed concrete for rock support. *Concrete*. The Concrete Society, Sep 2007

Tuesday 28th September 2010
ICE, One Great George Street,
Westminster, London SW1P 3AA

Tunnels & Tunnelling Conference 2010

opportunities & challenges in Tunnelling

in partnership with the

British Tunnelling Society

Chairman Martin Knights

Tunnels and Tunnelling International **and the** ***British Tunnelling Society*** **are proud to announce their second jointly organised conference, following the overwhelming success of last years event.**

This one-day event will feature presentations from both the UK, and the international tunnelling communities with an unbridled focus on 'technical' content.

After years of attending such events, and in a time when picking the right conference for you is vital, we know we can provide content that a tunnelling attendee will actually want from a day's lectures. We will be avoiding the less specific 'brochure' type programmes and marketing style presentations, focussing instead on topics that will benefit you as an engineer.

We will also be encouraging open and frank discussion between presenters and delegates on subjects close to the heart of the tunnelling industry.

Jon Young
Editor, Tunnels and Tunnnelling

Watch this space for further announcements but make **September 28th** a date at the ICE

For more information please contact:

Delegate registration:
conference@tunnelsonline.info

To exhibit and sponsorship opportunities: Shelly Palmer
Tel: + 44 (0) 207 936 6848 Email: spalmer@progressivemediagroup.com

British Tunnelling Society

tunnels & tunnelling CONFERENCE

Tunnels & Tunnelling International,
World Market Intelligence,
John Carpenter House, 7 Carmelite Street,
London, EC4Y 0BS, UK

BOOKING FORM

☐ Yes, please register the following delegate(s) to attend

TUNNELS & TUNNELLING CONFERENCE 2010
in partnership with **THE BRITISH TUNNELLING SOCIETY**

Company Details

Company Name.. Address..

Postcode.................... Tel.................... Fax.................... Website....................

Delegate 1

Title.................... First Name.................... Surname....................

Job Position.................... Email ....

Delegate 2

Title.................... First Name.................... Surname....................

Job Position.................... Email ....

Delegate 3

Title.................... First Name.................... Surname....................

Job Position.................... Email ....

Delegate Registration Fees (+17.5% VAT) & Exhibition Stands

☐ Standard booking price £395/$700/€475 before 27 August
☐ Late booking price £495/$890/€595 after 27 August
☐ Exhibition Stands £2500 + 2 Delegate Places

4 Easy Ways to Register!

- fax back to +44 (0)20 8269 7844
- conference@tunnelsonline.info
- +44 (0)20 8269 7833
- Post to: Natasha Denney, World Market Intelligence Ltd,
  Tunnels & Tunnelling Conference 2010
  Progressive House, 2 Maidstone Road, Foots Cray, Sidcup, Kent, DA14 5HZ UK

Payment Methods

Payments may be made by cheque, bank transfer or credit card. Your places must be paid before the conference begins
Please tick the appropriate box of your preferred payment method:

☐ Cheque: crossed cheque payable to World Market Intelligence Ltd and write on the back of the cheque "T&T Conference 2010"

☐ If you wish to pay by credit card, please fill in the following details:

☐ Visa ☐ MasterCard ☐ American Express ☐ Bank card No.................... Expiry Date....................

Name (as appears on card).................... Signature....................

☐ Bank transfer. Please use your 'name + T&T conference 2010 + invoice number' as reference on all transfers. Transfers should be made to World Market Intelligence Ltd

Bank Details: Lloyds TSB Bank Plc

Address: PO Box 72, Bailey Drive, Gillingham Business Park, Gillingham, Kent ME8 0LS

Currency	Sort Code	A/C No	BIC	IBAN
STG	30-00-02	00310420	LOYDGB2LCTY	GB18 LOYD 3000 0200 3104 20
EUR	30-12-18	86368887	LOYDGB2LCTY	GB12 LOYD 3012 1886 3688 87
USD	30-12-18	11638084	LOYDGB2LCTY	GB64 LOYD 3012 1811 6380 84

Venue Details

The Ice, One Great George Street, Westminster, London SW1P 3AA

Booking Conditions: This booking form constitutes a legally binding contract.
Substitutions/cancellations: All cancellations must be made in writing. Substitute delegates will be accepted at any time, any changes must be made in writing.
Bookings cancelled before August 27 will receive a 50% refund and access to the conference papers.
Booking cancelled after August 27 will receive no refund but will have access to the conference papers.
Tunnels & Tunnelling will endeavor to ensure that this conference programme is correct at the time of print. Tunnels & Tunnelling reserve's the right to change the conference/workshop content, timing, speakers or venue without notice. The event may be postponed or cancelled due to circumstances beyond the control of Tunnels & Tunnelling. If a situation arises, we will endeavour to reschedule the event. However, Tunnels & Tunnelling cannot be held responsible for any cost, damage or expenses which may be incurred by the customer as a consequence of the event being postponed.
We also reserve the right to cancel his conference in which case full refunds will be issued.

Choosing the right fibre for the right use

Benoit de Rivaz, global Tunnelling manager of Bekaert (Building Products, France) presents his opinions and supporting evidence on choosing the correct fibres for reinforcing concrete in underground applications

Steel-fibre reinforcement has been used for many years in sprayed concrete in tunnels for temporary and even final lining. Multiple research studies and tests on the behaviour of steel-fibre-reinforced concrete (SFRC) have been carried out in recent years in various countries. They have greatly contributed to a better characterisation of SFRC, and have thus allowed a better understanding of the behaviour of this material and to specify minimum performance requirements for each project. The state of the art is well-known and lot of international standards provide clear guidance and performance criteria to use SFRC safely. Macrosynthetic fibre is also proposed today for different applications. Specific technical strength and weaknesses of the different fibres are often less well-known, and lead to confusion. This paper discusses the important characteristics of steel- and polymer-fibre-reinforced sprayed concrete when used for ground support, and provides the latest test results from different laboratories.

Material properties

Young's Modulus

The reinforcing ability of a fibre depends on the anchorage of the fibre into the concrete, the tensile strength and its Young's Modulus.

The Young's Modulus of concrete is typically 30,000MPa; of steel fibre it's typically 210,000MPa and of polyolefin fibre it's typically 3000-10 000MPa.

For well-anchored fibres, and equal demands on the fibre, the elongation of polymer fibre, and the corresponding crack width in concrete, might be considerably higher compared to steel fibres. This might have an impact on the durability of the concrete, especially in combination with traditional reinforcement.

Tensile strength

The tensile strength of steel wire is typically 1,000-2,000MPa compared to 300-600MPa for macrosynthetic fibre.

Specific density

The specific density of steel fibres is typically 7850kg/m3 compared to 910kg/m3 for polymer fibres, and 1000kg/m3 for water. Polymer fibres are light, which is favourable for health and safety, but they are lighter than water: the polymer fibres actually float on water, with potential risks for fibres at the surface.

Fire resistance

Metallic fibres have a neutral to positive impact on the fire resistance of structures. Due to a decreased spalling effect, a structure in metal fibrous concrete behaves rather better in the presence of fire than a mesh-reinforced structure for segmental lining, according to tunnelling specialists. Steel keeps its mechanical performance up to a temperature of 350C to 400C.

Macrosynthetic fibres, though, start to lose their mechanical properties as soon as the temperature reaches 50C and even disappear at 160C. In a fire a structure with macrosynthetic fibres alone soon becomes unreinforced, with no load bearing capacity left at all, and may result in an unsafe situation from the first hours onwards.

Polypropylene microfibres typically melt at temperatures around 160C. Therefore these fibres (monofilament, length 6mm, diameter nominally <20μm) are proven to be suitable to improve the fire resistance. The exact reason is now fully-understood, as it's generally accepted the microfibres start to melt in extreme fire conditions, thereby leaving small channels through which the pressurised vapour can escape. Consequently less damage from less spalling of the concrete is to be expected.

Macrosynthetic fibres melt at an equivalent temperature, but are not fine enough to provide the concrete under fire with the necessary network of channels. Moreover since the fibres melt, they are not suitable in those structures where the reinforcing effect of the fibres is important.

Oxidisation resistance

Polymer fibres don't rust, even if the fibres are sticking out at the surface. Regarding metallic fibres, experience and research conclude:

- Steel fibres need only a concrete cover of 1-2mm compared to 30-40mm for normal rebar and mesh
- Corrosion of the fibres at the surface may cause discoloration but does not affect the mechanical properties of the SFRC structures
- Fibres in crack openings smaller than 0.25 mm do not corrode (see Brite Euram project)
- When no stains are required, galvanised steel fibres can be applied

Mix ability

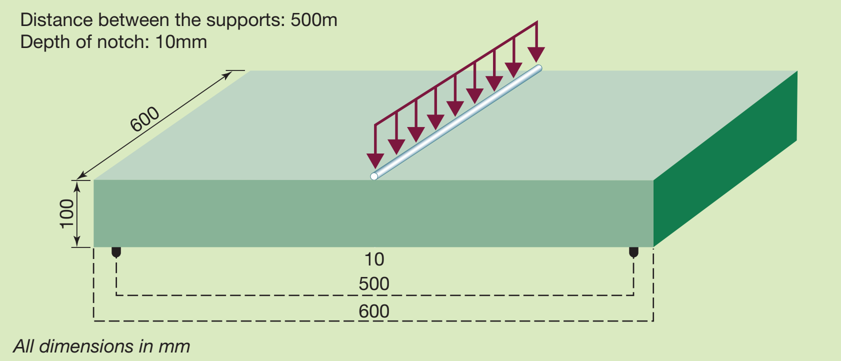
Some macrosynthetic fibres tend to fibrillate during mixing. This fibrillation process can go on in the truck mixer until all fibres are completely destroyed. Quality degradation during mixing does not occur for steel fibres.

Concrete fibre content

European Standard 14721 specifies two methods of measuring the fibre content of metallic fibre concrete.

Method A measures the fibre content of a hardened concrete specimen. Method B measures the fibre content of a fresh concrete specimen.

There is no method available for polymer fibres at present in order to meet the quality control requirement for many projects.



Above: **Figure 1 – three-point bending test for residual strength**

Waterproofing membrane

Double-shell tunnel construction includes a waterproof membrane in between the sprayed concrete support and the final cast in situ concrete layer combined with a geotextile as a buffer to level out the irregularities of the sprayed concrete.

There was a concern about the danger of steel fibres protruding from the sprayed concrete surface to punch through the waterproof membrane.

In 1993 CETU (the French tunnel administration) had already financed puncture tests (under hydraulic pressure) on the geomembrane (600g/m2) placed on fibre-reinforced sprayed concrete support. These revealed the importance of the lower protective geotextile, without, however, revealing puncturing risks when it was placed between the PVC geomembrane and the fibre-reinforced sprayed (at that time Dramix fibres type RC65/35BN were tested).

As other tests were performed and with practical experience on many sites, test results confirm clearly that there are no problems with the membrane/protection sheets in combination with steel-fibre-reinforced sprayed concrete.

However for some projects 30mm of non-fibre concrete are applied. In fact the key issue remains the irregularities of the sprayed concrete. It should be noted that several experiments have been carried out on the use of macropolymer fibres in sprayed concrete. The presence of these polymer fibres may increase the roughness of the support irregularities formed by the fibre/concrete mix.

Recommendation on this subject remains in discussion.

Properties of fibre concrete

Fibre concrete is well-known for its ductility. The effect of fibres is a combination of reinforcement and networking. Steel fibres in particular change the behaviour of the concrete: steel fibres transform a brittle concrete into a ductile material, which is able to withstand fairly large deformations without losing its bearing capacity. Ductility means load redistribution and a higher bearing capacity of the structure with the mechanical properties of the basic concrete material unchanged.

Usual performance criteria

The test plate usually used (600 by 600 by 100mm panels) (see European Standard EN 14.488-5) is designed to determine the energy absorbed from the load/deflection curve. Slabs intended for the punch-flexure test shall be made in receptacles of 600 by 600 by 100mm. In this case care will be taken to obtain an even surface and a thickness of 100 mm.

Spraying shall be carried out rigorously under the same conditions as recommended for the works: constituents, machine, lance holder and spraying methods in particular.

This approach tries to simulate the real lining behaviour. It gives a good idea of the load bearing capacity and the energy absorption of a sprayed concrete lining.

Instead of determining a material characteristic, which requires a proper design model in order to calculate the allowable solicitation of the structure, the EN plate test approach allows skipping that step and immediately checks the energy absorption and the load bearing capacity of the lining.

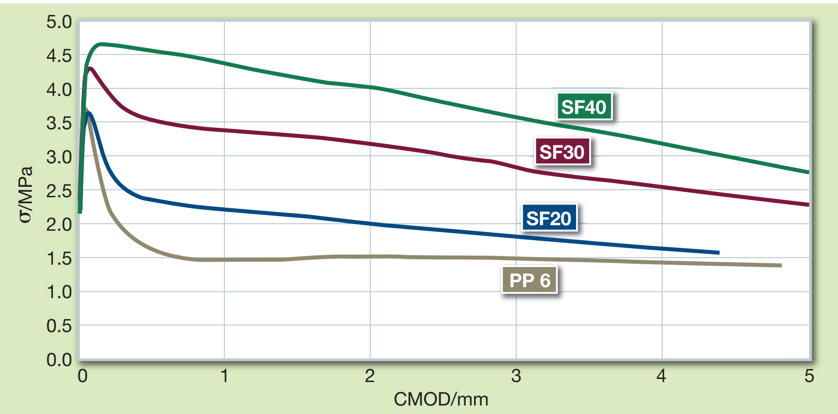
It has to be stated very clearly that the statically indeterminate slab test is a structural test to check the behaviour of a construction. It is not a test to determine material properties to be used as design values. Based on this plate test, three SFRSC classes (E500, E700, and E1000) are defined for a C30/37 mix:

- 500 Joules for sound ground/rock conditions
- 700 Joules for medium ground/rock conditions
- 1,000 Joules for difficult ground/rock conditions

These values are proposed for the C30/37 class, usually specified for a temporary support. Compressive strengths with a too low and too high strength class may have undesired side effects.

In the case of higher compressive strength, the performance criteria proposed by the EN standard should be increased in order to keep the same level of ductility required for safety.

The plate test is also appropriate for a comparison of different fibre types and dosages. It allows for a comparison between mesh reinforcement and fibre reinforcement concrete, provided that the failure mode is the same according to EN 14 487-1 "Sprayed concrete, definition, specification and conformity." That is why the performance criteria based on this test and the currently proposed test should only be used to compare steel mesh and steel fibres (material with same the same Young's



Left: **Figure 2 – Flexural strength results for crack-mouth opening displacement (δ - CMOD)**

Modulus - E).

The relative importance of load carrying capacity at small crack widths—and hence small deflections and rotations—is, in recent times, assuming much greater importance to the designers of civil engineering tunnels.

Due to the very low Young's Modulus - E of macrosynthetic fibres and the mode of failure observed with this type of fibre, the plate test is not sufficient to compare steel fibres and macrosynthetic fibres. In the case of polymer fibre another criteria should be added in order to have complete information, such as residual strength.

Residual strength

To determine the residual strength, the European EN 14651 is mainly used: Test method for metallic fibered concrete - Measuring the flexural tensile strength (limit of proportionality [LOP] residual) (Figure 1).

This test procedure is mentioned in the final recommendation of Rilem TC162TDF "Test and design method for steel fibre reinforced concrete."

This European Standard specifies a method of measuring the flexural tensile strength of metallic fibre concrete with a wide-beam moulded test specimen. The method provides for the determination of the LOP and of a set of residual flexural tensile strength values.

This testing method is intended for metallic fibres no longer than 60mm. The method can also be used for a combination of metallic fibres and, a combination of metallic fibres with other fibres.

The characterisation test enables the contractor who proposes a fibre-reinforced concrete (FRC) to check that this FRC satisfies the "mechanical" specification resulting from dimensioning.

In order to improve this approach, we could propose to follow the following requirements:

- The geometry and dimensions of the specimens, as well as the casting method adopted, should ensure distribution of the fibres in the matrix that is as close as possible to that encountered in the actual structure as spray concrete or flooring
- The dimension of the test specimen is acceptable for handling within a laboratory (no excessive weights or dimensions)
- The test is compatible, as far as the experimental means permit, with use in a large number of normally equipped laboratories (no unnecessary sophistication)
- The geometry should be the same as in the EN 14 488-5 plate test for energy absorption
- One geometry for isostatic and hyperstatic tests
- An easily managed test programme could use spraying on the job site with the same procedure as the plates test giving lower scatter than the beam test. These are results (Figure 2) for different CMOD (crack mouth opening displacement) according to EN 14 651 using: PP = Macro-polymer fibre dosage 6kg/m3; and SF20/30/40 = Steel fibre (Dramix RC65/35BN) at dosages of 20, 30 and 40kg/m3.

After the first cracking, the load bearing capacity of macrosynthetic fibre concrete dropped down about 60 per cent rapidly. This means that the 6kg/m3 fibres have lower influence on the residual strength than steel fibres.

A higher dosage of macrosynthetic fibres will have big influence on the concrete mix workability and pumpability.

Creep of fibre concrete

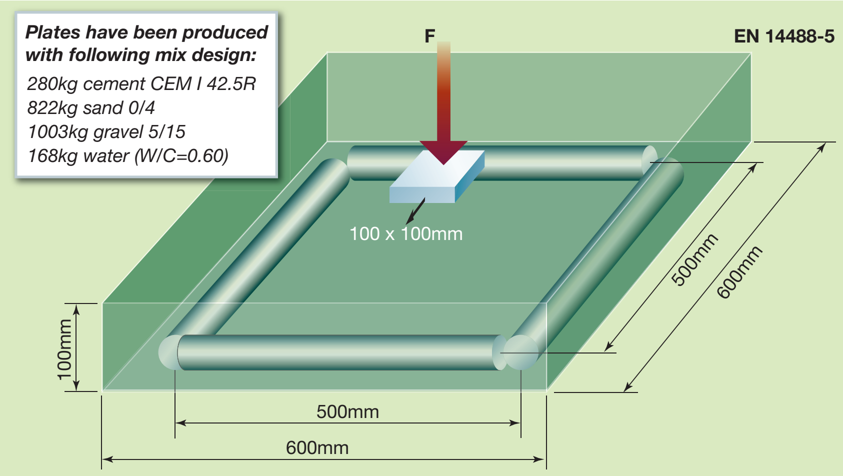
Sample plates have been tested in a displacement-controlled manner as described in EN 14488-57. At a deflection of 3mm the load was removed.

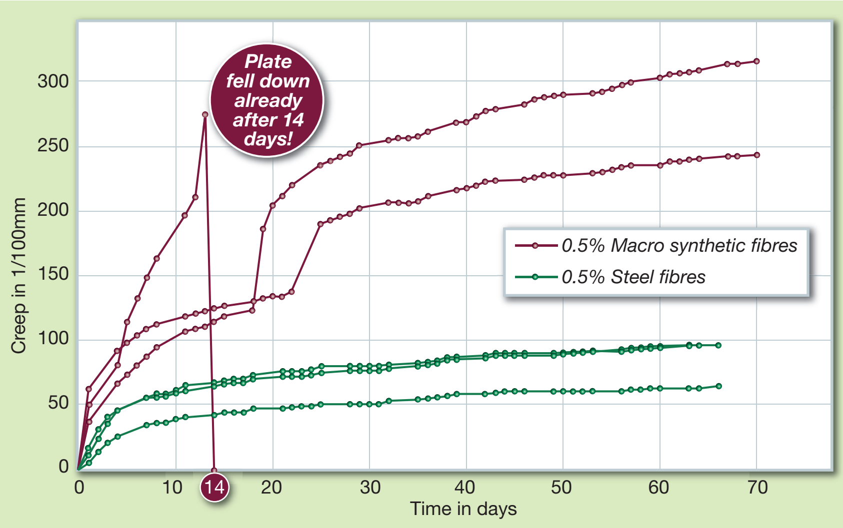
The plates were then ready to be subjected to the creep test and were reloaded with 60 per cent of the applied load at a deflection of 3mm. The deflection was measured and shown on the y-axis in 1/100mm increments as on the graph (figure 4).

The consequence of creep is that the material will not provide significant reinforcement with the aim of stabilising the ground and minimising any future movement that may well be necessary.

Design rules

Since October 2003, Rilem TC 162-TDF1





Above right: Figure 3 – Creep test with a square panel according to EN 14488-57
Right: Figure 4 – Creep results on a square panel

design guidelines have been available for steel fibre concrete. No such guideline is available yet for macrosynthetic fibre concrete.

Quality control

As part of the production quality control wash-out tests are quite common in order to check the dosage of fibres in fresh concrete. This is possible when the fibres can be removed by a magnet, as is the case for steel fibres.

References

[1] Rilem TC membership, chairperson Vanderwalle, L. TC162-TDF: Test and design methods for steel fibre reinforced concrete, Materials and Structures, Vol 36, October 2003, pp560-567.

[2] Rossi. Tunnels and Tunnelling International, July 2009 pp28-32, Progressive Media Group, London.

[3] Allen, C. Fibre Decider, Tunnels and Tunnelling International, October 2009 pp35-37, Progressive Media Group, London.

[4] Lambrechts, AN. The Technical Performance of Steel and Polymer Based Fibre Concrete, Concrete for a New World, - The Institute of Concrete Technology Annual Technical Symposium, 5 April 2005.

[5] Ratcliffe, R. Steel versus Synthetic Fibre Reinforcement Shotcrete.

[6] European Standard EN 14 487-1 Sprayed concrete, definition, specification and conformity.

[7] European Standard EN 14.488-5 Testing sprayed concrete - Part 5: Determination of energy absorption capacity of fibre reinforced slab specimens.

[8] Brite Euram Project – Durability: Final report.

Conclusion

Steel fibre used for sprayed concrete has proven over the years to be a reliable construction material for tunnelling applications. After 30 years of experience, the return of experience is very positive. Official international standards are now available.

Macrosynthetic fibres may be used in sprayed concrete support for some mining applications (perhaps in combination with mesh) or specific technical needs.

However, only steel fibres (no macro-polymer fibres) can act as structural reinforcement of concrete for the following reasons:

- Polymer fibres melt at 165C; in a fire any reinforcing effect of the macrofibres fades away as the temperature rises.
- The Young's Modulus is 3-10MPa, which is largely insufficient to reinforce concrete material with a modulus of 30MPa.
- Macro-polymer fibres creep (see elaboration above).

Clear test procedures and performance criteria should be specified for each project in order to meet technical requirements.


• Backfilling (one or two components)
• Pre-excavation grouting
• Post/consolidation grouting
• High-Shear Mixers up to 2500 litres
• Grout pumps up to 200 bar
• Pressure and flow recording systems
• Compact grout plants
• Bentonite modules for microtunnelling
• Fully automated grout plants
• Backfill systems for one or two component grouts
GROUTING SYSTEMS
HÄNY
Häny AG • Buechstrasse 20 • CH-8645 Jona/Switzerland
Tel. +41 44 925 41 11 • Fax +41 44 923 62 45 • info@haeny.com • www.haeny.com


CONSTRUCTION
ENERGY
MINING
OSSA, OVER 50 YEARS OPENING THE WAY UNDERGROUND
OSSA is a leading international underground specialist contractor with over 50 years experience in major tunneling and mining projects. Over the years our focus has been to meet our clients demands by specializing and improving our core strengths in the underground sector. Our projects range from the most complex metro, railway, roadway and hydraulic tunnels to large mining galleries, caverns and shafts.
AENOR
ER
Empresa Registrada
ER - 0400/1996
AENOR
Gestión Ambiental
CGM - 03/213
C/ Aragoneses, 2-A, Plta. 3ª. Pol. Ind. Alcobendas. 28108 Alcobendas (Madrid)
T. +34 902 678 808 | T. +34 917 823 400 | www.ossaint.com
OSSA
OBRAS SUBTERRANEAS
The Reliable Tunneling Partner

Segment fibre reinforcement in Barcelona

Bernard Berge, product specialist engineer of the Maccaferri fibre division examines the successful use of fibre-reinforced concrete in tunnel lining segments used in the construction of Barcelona's impressive new metro system

Fibre-reinforced concrete (FRC) consists of a cementitious, hydrated paste into which reinforcement fibres, usually small, steel filaments about the size of a paperclip, are mixed.

The fibres redistribute the forces within the concrete, restraining the mechanism of formation and extension of cracks. The result is a more ductile concrete that is able to maintain a residual capacity in the post-cracking phase. Steel fibres within the concrete literally stitch the sides of a forming crack together.

Micropolymer fibres, which are thinner than a human hair, are often used in conjunction with the steel structural fibres to provide greatly enhanced fire resistance. These polymer fibres melt when exposed to great heat, leaving multiple microscopic tubes within the concrete into which latent moisture can evaporate. This moisture would otherwise cause explosive spalling of the concrete as it would have nowhere to expand to within the concrete matrix.

The principal benefits of FRC are reduced shrinkage cracking, increased impact and fire resistance and a reduced need for conventional steel bar reinforcement.

In the UK, FRC has found favour mainly for the industrial floor slabs arena where its improved impact resistance characteristics are especially beneficial in applications where high or aggressive traffic loadings are expected.

In Europe, FRC, with both steel and polymer fibre, has a far more enthusiastic following with applications across a wide range of civil engineering applications.

Above: **Barcelona's Metro is making use of precast tunnel lining segments with steel reinforcement fibres**

Barcelona Metro

In Spain, construction of the 43km extension to the Barcelona Metro has made extensive use of precast tunnel lining segments incorporating steel reinforcement fibres.

When completed it will be the longest and one of the deepest lines in Europe and the longest metro line in the world of entirely new construction. It will also be the most expensive enterprise the Catalan government has ever undertaken. The final projected costs are believed to be close to EUR 6.5bn (USD 8.15bn) in 2012.

Three joint venture contractor groups, UTE Gorg, UTE Linea and UTE Aeroport, used precast FRC segments for lining their three sections of the 12m diameter tunnel totalling 11.7km in length.

At the 3.8km Sagrera TAV-Gorg section, construction work began in 2003. An EPB TBM was used to excavate the tunnel, with the precast lining segment rings erected mechanically behind.

During the tunnelling process the hydraulic thrust jacks on the TBM work off the precast concrete segments. Overall thrusts of up to 140MN can be reached during the jacking process, with a normal working range of between 90 and 120 MN.

The excavated diameter of the tunnel is 12.1m with an overall lining thickness of 400mm, including the precast concrete lining.

Segment fabrication

FRC tunnel ring segments were cast off site with rings comprising seven segments of 4.56m length (48 degree length of arc) plus a 24 degree keystone. Each ring has width of 1.8m and is 350mm thick.

Segments were cast in curved steel moulds with vibration applied to consolidate the concrete mix, and then heat cured at 40C to 50C for four to six hours, before de-moulding and stacking in an open yard.

Correct forming of the concrete in open curved moulds required a mix of stiff consistency (hence low workability). In turn, this led to the need for higher amplitude vibration. The top surfaces of the segments were finished manually.

The original design for precast segments required 120kg of traditional steel reinforcement in the form of a prefabricated cage, to provide the required structural strength. No fibre reinforcement was considered at the time.

An initial proposal of 30kg/m3 of Maccaferri Wirand FF1 steel reinforcement fibres was made in an attempt to reduce the amount of steel bar within the segments. Testing resulted in refinement of the fibre reinforcement and a new fibre, Wirand FF3 with a higher length/diameter value of 67 was developed, offering improved performance.

Eventually, only 25kg/m3 of Wirand FF3 was found to achieve the same performance as 30kg/m3 of the FF1 fibres. More testing was implemented and the amount of steel rebar was gradually reduced. A final optimised combination of 25kg of Wirand FF3 fibres and 54kg/m3 of steel rebar gave the required structural performance (28-day compressive strength of 40MPa).

This design specification gave the strength to provide adequate performance during the placement of the segments and during the early service life of the tunnel. An early age compressive strength of at least 40Mpa (2900psi) was also required to ensure sufficient crack resistance during the de-moulding and stacking phase, so curing accelerator additives were used in the mix.

Reinforcement fibres are added to the concrete mix via purpose-made dosing equipment with a design specially modified by the supplier to ensure controlled introduction and consistent dispersion of the fibres. Five feeder machines were installed in the batching plant producing segments for all three lengths of tunnel.

To minimise seepage of water into the tunnel, crack widths were limited to 0.2mm, requiring a minimum 4-point loading flexural strength of 2.9MPa. Steel fibres, with high-strength/low-strain characteristics offer this performance; 25kg/m3 of Wirand FF3 offered a flexural strength of 3.5MPa.

The inclusion of reinforcement fibres also helped reduce the flexural stresses experienced during de-moulding and stacking, and controlled shrinkage cracking and thermal cracking caused by sudden temperature changes when segments were moved from the curing chamber to storage yard.

Similarly, the lining segments were shown to have good resistance to accidental impact damage as well as the highly concentrated loads imposed during segment placement and the application of the jacking forces from the TBM; often a critical phase for precast lining segments.

Fibre-only reinforcement

Months into the tunnel construction programme, contractors proposed an alternative method of casting lining segments, this time without the inclusion of steel cage reinforcement and relying solely on steel fibre reinforcement for the structural integrity of the unit.

The high cost of steel cage reinforcement and reduced casting time/increased mould utilisation were the principal motivations behind the proposal. The proposal was a revolutionary step, as this had not been considered for the final lining of tunnels.

In 2003/04 laboratory trials were carried out in conjunction with Maccaferri at the University of Bergamo in Italy to ascertain the viability fibre-only reinforcement. Fibre content was increased from 30kg/m3 to 60kg/m3 to replace the steel cage, yet maintain the required structural performance.

A series of measurements was implemented to evaluate the performance of the revised units, including:

- Finite element analysis to calculate the stresses incurred during stocking, handling and installation
- Characterisation of the flexo-traction resistance of the fibre-reinforced concrete with laboratory tests to prove actual material resistance
- Full scale in situ testing, installing approximately 20m of tunnel permanent final lining using segments reinforced with steel fibre only.

The results of the laboratory and site trials were presented at the 6th Annual RILEM Conference in 2004, and it was concluded that the segments reinforced with 60kg/m3 steel fibre could satisfy the project requirements without needing the inclusion of conventional steel bar cage reinforcement.

Despite the evident success of the trials, it was ultimately decided that the use of fibre-only reinforced concrete segments was a technological step too far for the project team, having already reduced rebar content from 120kg/m3 to 54kg/m3 through the use of fibres.

Fire protection legislation

Recently introduced Spanish legislation concerning fire protection in tunnels has obliged contractors to incorporate polymer fibres into precast lining segments. Along with its steel materials, Maccaferri is also supplying Fibromac FR polymer fibres to the project.

At the conclusion of the works in 2012, the company will have supplied approximately 20,000t of steel and polymer reinforcement fibres to the Barcelona Metro construction project.

Conclusion

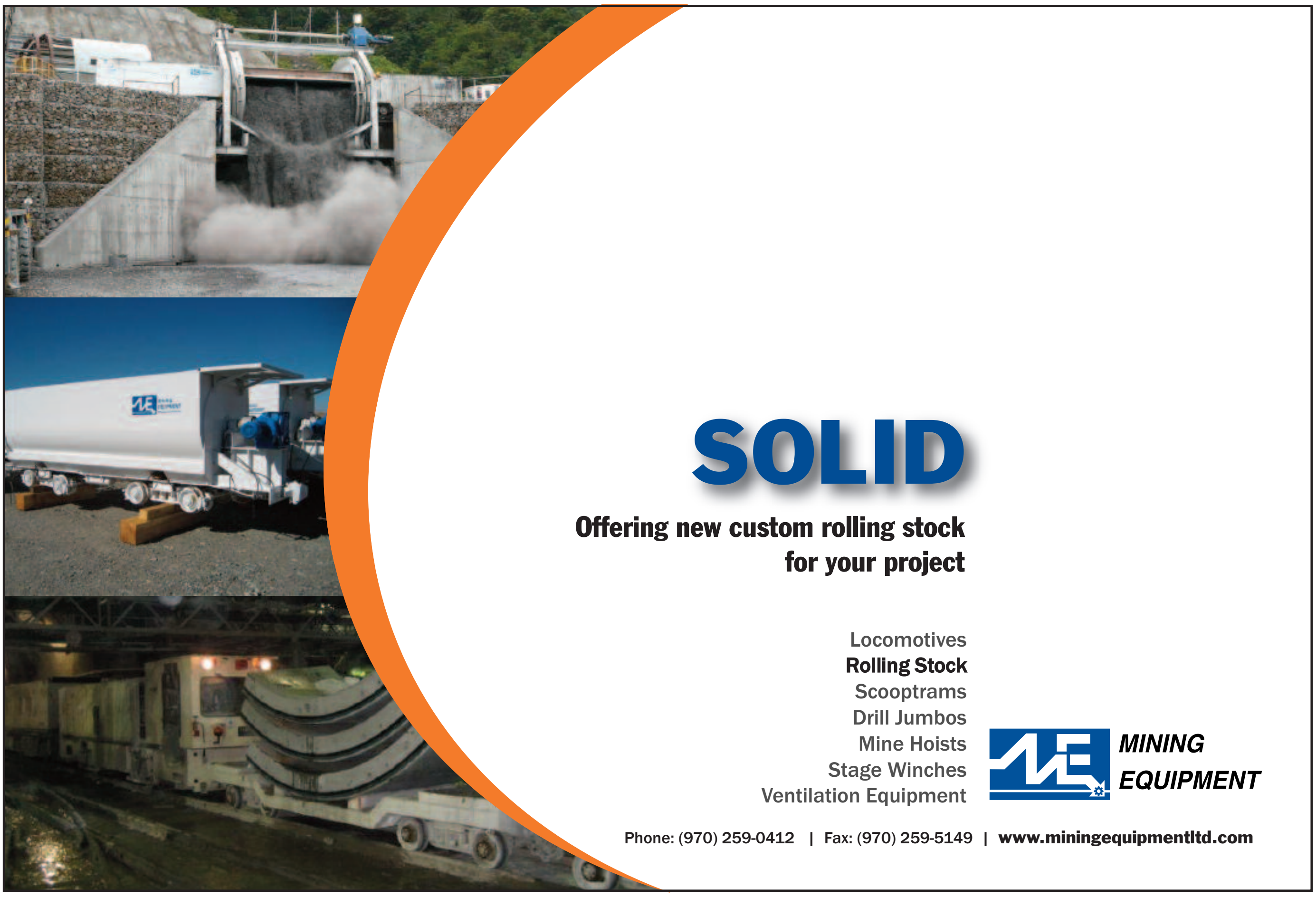
The implications of the Barcelona Metro trails may influence the future design and construction of tunnels. Through a willing project team comprising contractors, designers, material suppliers and research, cost savings and performance enhancements were made possible.

A paper describing the author's work on the development of fibre reinforced concrete for tunnel linings at the Barcelona Metro, was presented at the BPCF Conference 'Concrete 2010' in May at Leicester.
www.concrete2010.org

Maccaferri

Maccaferri specialises in retaining structures, erosion protection and soil reinforcement and offers design support, technical advice and where appropriate, indemnified design and construction services. The company is traditionally known for the production of wire mesh 'gabions' used for erosion protection and slope reinforcement in rail, road and waterway applications and has seen significantly expansion over recent years. It now operates over a wide range of geotechnical and civil engineering disciplines.


GONAR-SY STEMSINTERN ATIONAL
As a producerof highadvancedsystemsf ordrilling,cuttingtools,anc horing, umbrellasandc hemicalinjections(P olyurethaneandSilica tes)w ecanof fer comprehensivehelpinanytec hnicalpr oblemsy oumet.
Self DrillingAnc hor
Gonlex(frictionbolt)
Umbrellasystems
SN Anchor
Fiber glassbolt
Injection systems and pumps
Drilling and cutting tools, bolting systems, consolidation, structuralbonding, waterpr oofingandsealing, filling of cavities can be solvedwithoursystems assisted by our engineers using special designed developedsolutions.
GONAR-SystemsInter nationalSp .zo .o.
Obroki109,40-833Ka towice,P oland
Tel.+48322071201,F ax.+48322071250
www.gonar-systems.com


SOLID
Offering new custom rolling stock for your project
Locomotives
Rolling Stock
Scooptrams
Drill Jumbos
Mine Hoists
Stage Winches
Ventilation Equipment
MINING EQUIPMENT
Phone: (970) 259-0412 | Fax: (970) 259-5149 | www.miningequipmentltd.com

Two-component backfill grouting on Rome's Line C

Four EPBMs are being used to excavate Rome's Metro Line C Project under the city's historic buildings, streets and monuments. A two-component backfilling system is being employed on the project to perfectly fill the annular space behind the concrete segments and minimise the superficial subsidence. Enrico dal Negro, Alessandro Boscaro and Richard Schulkins of the Mapei underground technology team and Gianluca Gulino of the Metro C mechanised tunnelling department give this paper

As a shielded TBM advances, an annular void is inevitably created behind the concrete lining. This void has to be completely filled with an appropriate material as soon as operationally possible. This is to minimise ground movement, lock the ring in its design position and guarantee a homogeneous strength, leading to evenly distributed transmission of pressures between the soil and concrete.

Different solutions for filling the annular space have been tested. The most traditional material, especially in Europe, is a cementitious grout—made up of water, cement and chemical admixtures, and able to improve the mix pumpability and to regulate its setting time. Bentonite can be added to stabilise the material and improve its waterproofing properties. Sometimes, particularly with French constructors, cement is not used.

In recent years, both tunnel designers and TBM manufacturers are introducing more and more the two-component backfilling system, composed of:

• Component A: a super-fluid grout, comprising cement, water and bentonite; dosed with a retarding agent able to guarantee its workability and pumpability even over long periods and distances.
• Component B: an accelerator admixture, added to Component A immediately prior to its injection, enabling an almost immediate jellification of the mix.

The main advantages of this system over other filling materials are:

• Its super-fluid consistency and workability maintenance that minimises the risks of clogging transport lines and pumping pipes. Pumping the grout over several kilometres obviates the need for grout cars.
• Its ability to completely fill the annular space behind the ring, minimising ground movement and consequently risks of subsidence.
• The very quick hardening, even in presence of underground water, which allows a rapid development of early-stage mechanical strengths, locking the ring in its design position. The fast gelling action also reduces losses through the tail-brushes.

Grouting Line C

A joint venture of Astaldi, Vianini Lavori, Ansaldo Trasporti-Sistemi Ferroviari,

Right: **Final tank where the Component A is stocked and then pumped to the tunnels**

Cooperativa Muratori e Braccianti di Carpi, Consorzio Cooperative Costruzioni is constructing Metro Line C in Rome.

Four EPBMs, manufactured by Herrenknecht, have excavated approximately 12km of tunnels up to date. Most of the alignment is through pozzolanic soil with the presence of ground water.

The EPBMs are equipped with a backfill grouting system (pumps, lines, etc.) designed for use with two-component materials.

The two-component ingredients and their respective dosages have to be carefully studied in order to achieve the most appropriate solution, both from a technical and economical point of view. Every project has its peculiarities; therefore it is necessary to adapt the mix-design of the two-component mix to the specific requests of each job site.

Above and Left: **Views of the batching plant in the Line C job-site**

The first step is the choice of the raw materials. In particular, bentonite is the most important material to be selected. Technically, the bentonite chosen should be able to guarantee the quickest activation/hydration with the available water supply. This means that bentonite, after being mixed in a high speed colloidal mixer with water, starts hydrating in only a few minutes. This mitigates the pre-hydration operation that is common when using bentonite in other fields (for example, diaphragm wall slurries) that require large storage facilities.

The choice of the cement and its dosage mainly depends on the mechanical strength development requested in the project specification. In the Metro Line C project the specifications for compressive strengths relate only to the very short term and short term stages (until 24 hours from batching).

Another important parameter to consider is how the mix is to be transported to the TBM. In Rome, two different ways have been used: in the first two tunnels excavated (T6 alignment) a mortar car was used, while in the T5 lines the mix (Component A) is pumped from the batching plant directly to the TBMs. The second way requires a better volumetric stability of the Component A, where the separation between water and solid components ("bleeding") has to be almost zero. This avoids the settlement of solid materials in the pumping lines, which would cause their clogging and consequent long production breaks.

Also the choice of the batching plant to be used in the job site is of paramount importance. Its productivity and its storage capacity have to be carefully chosen according to the expected productivity of the TBMs. The mixer has to guarantee enough turbulence/shear in order to efficiently activate the bentonite and disperse the cement particles.

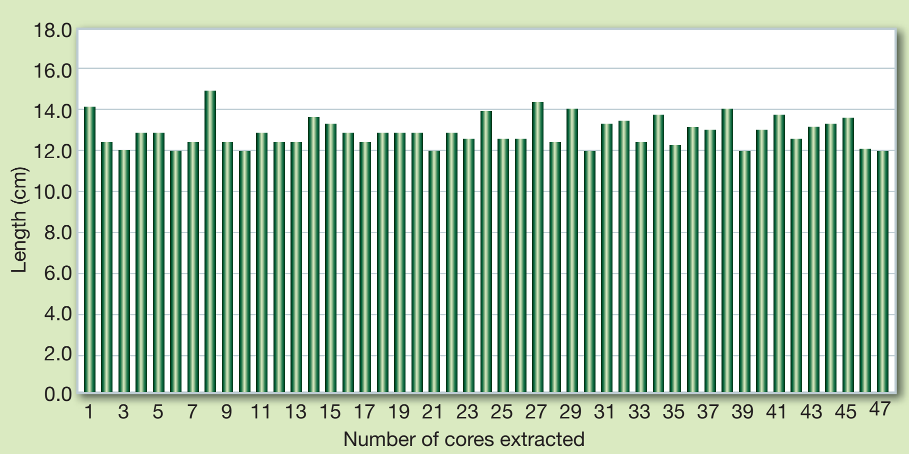
Keeping in mind all the specific requests, a number of tests have been carried out by Mapei's research and development laboratories in Milan. The aim was to test different raw materials, supplied by the contractor, their compatibility and the dosage of every ingredient.

Once a mix-design was established in the laboratory, the technical assistance of the Mapei underground technology team (UTT) continuously tested the backfilling material produced in the job site batching plant during the first weeks of the TBMs advances. The aim was to check if the results are comparable to those achieved in the laboratory.

Characteristics of the two-component material

The campaign of laboratory and in-situ tests lead to a mix-design that is able to guarantee all the requests that the backfill material has to achieve:

- Fluidity of Component A able to ensure easy pumping even for long distances.
- Workability maintenance of Component A that allows storage of the material over long periods (up to 72 hours from batching) mitigating cleaning over extended TBM breaks. This is possible due to the Mapequick CBS System 1, a highly-efficient liquid retarding agent with a plasticising effect. It is automatically added into the turbo-mixer after all the other ingredients and then mixed for a few minutes.
- Volumetric stability of Component A, which does not "bleed" and therefore minimises risks of clogging pipes. The right kind of bentonite and its appropriate dosage facilitated this.
- Almost immediate jellification after the addition of Component B to Component A. The time between the additions of the accelerator admixture (Mapequick CBS System 2) to the complete loss of workability has to be balanced. The time for gelling is balanced between avoidance of clogging the injection pipes, travelling around the annulus and gelling to avoid being lost through the TBM tail brushes.
- Early and very-early mechanical characteristics that avoid surface subsidence and lock the ring in its design position. Long-stage compressive strengths do not represent a significant parameter, as the main aim of backfilling material is to perfectly fill up the annular space left empty behind the ring while excavating.
- Low permeability that makes the filling material a barrier against ground water passing into the tunnel (a large benefit in ensuring the tunnel water-tightness is guaranteed in combination with gaskets and concrete quality).
- Stability and durability against eventual washing-out actions or chemical attacks from ground water, and vibrations due to train passages.



Above: **Length of the cores extracted in the tunnels.**

Injection

The Component A is batched in a plant located close to the tunnels entrance, which is connected with a mixing tank with capacity of approximately 5m3.

Then the Component A is transported in the TBM and stored in a mixer tank with capacity of 7m3, connected with n.6 screw pumps.

Component B (accelerator admixture) is stored in the TBMs in a 1,000l tank, which feeds n.6 screw pumps.

The TBMs are equipped with six injection lines, regularly distributed around the shield circumference. Normally only the upper four lines are used, because the flow that they can ensure is enough to fill the annular space left empty by the shield advance (average speed 30-35mm/min). Furthermore, the two lower lines are the most likely to choke.

Component A is normally injected at a pressure 0.1 - 0.2 bar higher than the EPB pressure. It is important not to use a pressure much in order not to submit the shield brushes to elevated strains. Elevated grouting pressures also often lead to ring deformation.

The injection is started when the TBM has already excavated the first centimetres of the advance, so that there is already an empty space to be filled. There are two criteria to stop the injection: the volume of injected material should achieve the desired one (normally the theoretical empty volume plus 15-20 per cent), and in every line the preset pressure should be reached. The achievement of the above proves the complete filling of the annular space behind the segments.

Regular cleaning of every injection line is carried out. After every advance, water at a pressure of 30 bar is injected, and approximately once a week every component of the circuit is checked and eventually replaced. The cleaning is important especially for the nozzle of the accelerator lines and to completely remove any hardened particles of Component B. Any undesired contact between Component A and Component B due to leakages in the nozzle would cause at least an impairment to the system.

Controls

Some relevant facts and controls are necessary to prove the efficient backfilling. This proves the procedures used for the injection are appropriate, as well as the chosen materials and their dosages.

The main properties of the two-component system are checked daily on the job-site. Characteristics of the Component A, such as its fluidity and volumetric stability, are measured, as well as the properties of the hardened material (after the addition of Component B), such as gel time, mechanical strength development up to 24 hours from batching, permeability, etc.

The effective 360 degree filling of the annular space is periodically inspected by extracting cores. To date all the cores have always shown the presence of the hardened two-component material behind the ring with the expected length (approximately 130-150mm).

An experimental test has been carried out. Several sensors have been inserted in the segments before the backfilling injection in order to measure the effective pressure of the two-component material. The measured pressures almost correspond to those set by the operator.

Furthermore, during some stages of the metro line execution, such as TBMs arrival in the final shaft, execution of stations, etc.,

Above: **The whole annular space has been filled with the two-component material.** Left and below left: **Extraction of a segment and presence of the two-component material in the annular space.**

some concrete segments had to be removed. This allowed a visual check of the backfilling material. In all the cases, the presence of the two-component mix could be noticed for the whole thickness of the annular space between concrete and surrounding ground.

Finally, it should be underlined that the tunnels are excavated in densely urbanised areas, below several roads, buildings and historical monuments. Therefore not to properly fill the annular space would be a huge risk. To date no significant subsidence has been measured on the surface.

Conclusions

It is possible to affirm that in the first 12km of excavated tunnels no significant problems associated with the two-component backfilling material have arisen.

The volumetric stability of Component A has been proven by the absence of blockages in the transportation lines from the batching plant to the TBMs. Also the injection lines of Component A and Component B are very seldom subject to problems, due to appropriate cleaning system.

Therefore downtime due to pipes choking is minimised or almost nullified. This is of paramount importance because sometimes, especially when using traditional cementitious mortars, the delays associated with pipe cleaning represent a significant loss of time and money.

Another advantage is that all the raw materials for the two-component systems used in Line C (cement, bentonite, Mapequick CBS System 1 retarding agent and Mapequick CBS System 2 accelerator admixture) are industrialised and therefore their origin and properties constantly controlled. Sand, which is always used in traditional cementitious grouts, can be subject to variations in its natural humidity content, which could lead problems in the final grout properties.

The almost immediate jellification of the material allows a very quick development of mechanical strength. The very early and early mechanical resistances, in combination with a complete filling of the annular space, minimise risk of surface subsidence. It's important to underline that the long stage strengths aren't significant for the backfilling material because the structural resistance of the tunnel must be guaranteed by the concrete segments.

Finally, the very fast gelling and the complete void filling reduce significantly the ring deformation, which could be due to the TBM shove forces.

Breaking new ground in Rome

Tunnellers on Rome's Metro Line C are pioneering a new technology in Italy by using a hydraulic seal to prevent groundwater seepage when breaking into the reception shaft. Gianluca Gulino, Marco Barbanti, Tommaso Paolini of Metro C – Mechanised Tunnelling Division give this paper.

Rome's Metro Line C is among the most significant and challenging infrastructure projects underway in the world today. Running through the heart of the city the project faces both logistical and historical challenges that are inevitable when building a critical piece of infrastructure in one of the world's oldest cities.

Construction of the project is being carried out under a turnkey contract. Client Roma Metropolitane has awarded the contract to the joint venture Metro C (formed of Astaldi, Vianini Lavori, Ansaldo Trasporti-Sistemi Ferroviari, Cooperativa Muratori e Braccianti di Carpi, Consorzio Cooperative Costruzioni), which has turned to the most sophisticated technology available to bore the twin 17.6km tunnels. It is using a total of four identical EPB-TBMs from Germany's Herrenknecht. With a cutter head diameter of 6.71m and a 10.7m shield length, the EPB machines are capable of cutting under the city at 88mm/min (see Table 1).

As far as the tunnel lining is concerned, it consists of precast reinforced concrete segments of a thickness of 300mm, internal diameter of 5.8m, external diameter 6.4m. Each prefabricated ring is 1.4m long and has six main segments with a key. The rings are of universal double tapered type and fit 19 possible different positions depending on the radius of curvature to be obtained. Segments are cast in a prefabrication plant by using a fixed formwork installation for concrete steam curing.

To date the bore itself has gone very well. The boring machines have already obtained excellent production rates, with an excavation length of approximately 10km over slightly more than one year of activity. They have also obtained satisfying results in terms of compliance with excavation parameters and measured surface-settlement values.

Table 1

Diameter of cutter head:	6.71m
Diameter of front shield:	6.69m
Diameter of tail shield:	6.67m
Shield length:	10.7m
Thrust cylinders:	19 pairs
Length of thrust cylinders' path:	2200mm
Total length (shield + back-up):	98m
Maximum speed of excavation:	80mm/min
Maximum total thrust:	50 600kN
Cutting head's max torque:	7000kN/m
Pressure sensors in excavation chamber:	6
Segment backfill grouting lines:	6
Foam injection lines:	7

Hydraulic seal equipment

TBM S-409, the first of the four tunnel boring machines to begin excavation activities, completed the section St. Torrenova – Shaft 5.4 (even-numbered track) on 3 October 2009. For breakthrough into the reception shaft (5.4) a metal ring system with hydraulic seal was used, allowing the TBM to bore through the wall with groundwater behind it. This technique was subsequently adopted for the second TBM – S-410, which reached the reception shaft on 25 October 2009, thus completing the same section along the odd-numbered track. This method was used as an alternative to tunnel-end grouting, and allows tunnellers to carry out either the launch phase and/or the run-out phase from a shaft or station, through a system of seals waterproofing the area around the TBM's shield to prevent possible water seepage from behind the walls.

For this reason it is worth underlining that the fourth and final TBM in operation, TBM S-479, will soon adopt that same system but not for final breakthrough into a shaft. Instead it will be used for restarting the bore after crossing the Teano Station. Were this equipment not available, a more common approach would be to use jet-grouted concrete blocks behind the shaft or station wall eye for a length exceeding the shield length so that, when the last wall is crossed through, the TBM shield has already bored one or two rings erected within the block itself, thus ensuring a water seal.

Left: **Table 1 – The capabilities of the Four EPB-TBMs from Herrenknecht**
Right: **The concrete shuttering pipe ring with radial pins**

Left: **The 2-seal ring can be reused in other projects of the same dimension and characteristics**

This is the first time in Italy that hydraulic seal technology for an EPB's reception phase has been used within a shaft. The reception (or run-out) phase is much more complex than the start phase, mainly due to the high-precision topographical guidance required for the TBM. It must be ensured that, when going through the metal ring, the shield's position has the lowest possible plano-altimetric deviation with respect to design. In fact, seal centering may be adjusted by means of hydraulic jacks, the maximum extension of which must not exceed 100mm along its radius. Another reason that the reception phase is more complex than launch is due to the pressure balance. After breaking through the wall, and up to going through the seal, the pressure of possible water flows, which may occur around the shield because of the void between soil and the shaft chamber, must be counter-balanced.

The equipment required for the hydraulic seal was manufactured by MSD-Herrenknecht, and consists of the following elements. Firstly a ring with radial pins (concrete shuttering pipe) is buried into a reinforced concrete template that is normally cast in situ close to the wall soft-eye (in this case, the concrete was previously cut to form the hole). This is a disposable element that will remain embedded into the concrete template.

The next element is a ring with two seals that is bolted to the concrete shuttering pipe. These two seals have two independent compressed-air circuits, ensuring a design maximum operating pressure of 7 bar. Such a ring may be adjusted, up to a maximum of 100mm along its radius, by means of hydraulic jacks. The metal structure is entirely reclaimable to be used in other projects with the same dimensions and characteristics.

The equipment also requires a temporary cover to balance groundwater pressure due to excavation face progress before pressure is exerted on the seals. The cover is bolted to the ring with a seal. Figure 1 shows the exploded layout before assembly.

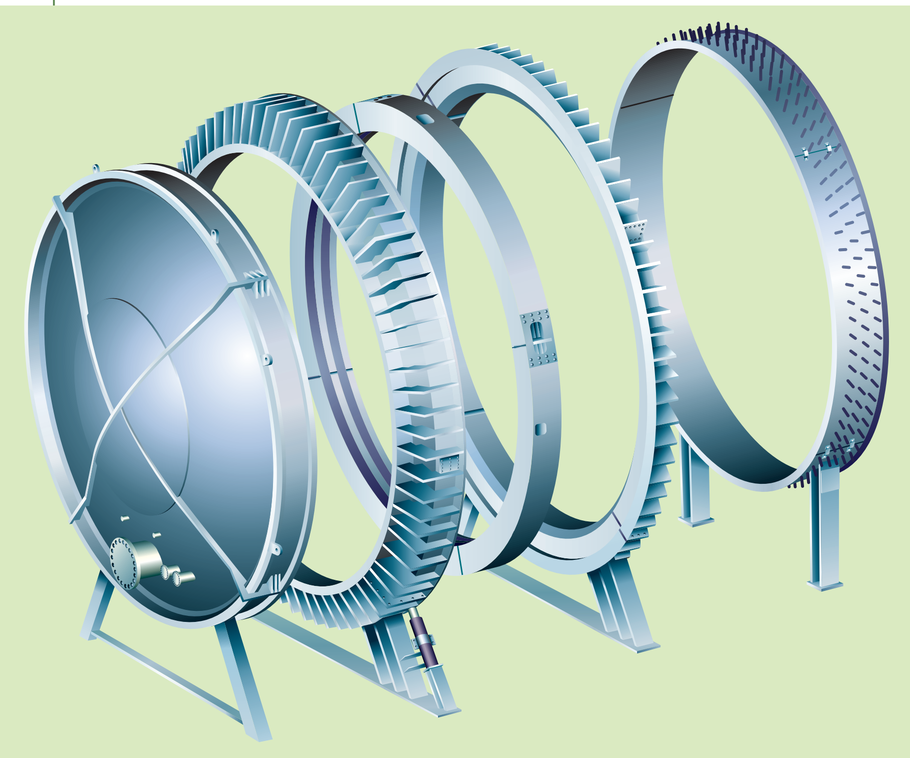
Geological and geotechnical aspects

From a geological perspective the ground to be driven through is essentially pyroclastic soils making up part of Latium's volcanic complex. The overburden above tunnel top ranges from a minimum of 6m up to a maximum of 24m. Groundwater load along the tunnel path is subject to changes but is present throughout the entire tunnel, apart from a section at one end, on the side of Torrenova Station. In the area where the tunnel intersects the shaft, groundwater head above the tunnel top is of approximately 9m.

Characteristics of the reception shaft (run-out shaft)

The round shape of the reception shaft

Below left and right: **A temporary cover is required to balance groundwater pressure. The cover is bolted to the ring.**



Above: **Figure 1 – A breakdown of the equipment required for the hydraulic seal**

required the construction of a reinforced concrete structure to anchor the equipment to the shaft wall. Moreover, the shaft's considerable depth and small diameter—which was necessary due to potential conflicts with surrounding pre-existent structures, and increased operational difficulties of installation with the equipment—deserve particular attention, as does the run-out and subsequent disassembly of the TBM. The shaft's walls were preliminarily cut at the position of intersection with the TBM, taking advantage of a jet-grouted zone, of length approximately 4m, consisting of plastic piles enclosed within concrete perimeter walls (Figure 2).

A similar procedure will be adopted, within the twin shaft, for the breakthrough of the second TBM carrying out excavation along the same direction and, in the future, also for the other two TBMs excavating toward the opposite direction.

Operational method adopted for TBM breakthrough

The breakthrough operations by using the metal ring requires the preparation of a detailed sequence of construction phases starting from the most recent excavation progress (approach to the last wall to be crossed through) and until the shield has gone through the seals and pressure is exerted on the latter.

a) Assembly of the equipment elements in the run-out shaft.

b) Progress of TBM excavation under earth-pressure balance mode until the shield runs into the grouted zone.

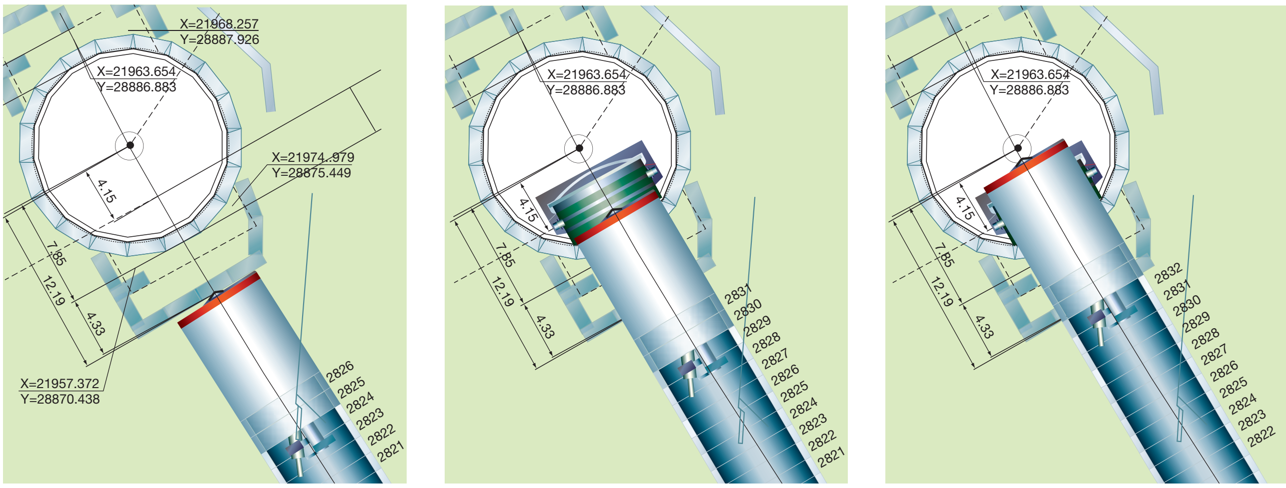
c) Progressive reduction in pressure supporting the excavation face during the last meters of excavation and until breaking through the last diaphragm. During this phase, the backfill is carried out in non-consolidated soil and, therefore, there is still the possibility of water inrushes between the shield tail and the excavation face.

d) Breakthrough and void crossing (for approximately 5m, corresponding to three to four progress steps) toward seals, while still keeping the cover closed. During this phase, several supplementary activities have to be carried out including disassembly of peripheral tools, which might damage the seal; removal of muck accumulated in front of cutting head consequently to the breakthrough; removal of provisional protections from the seal in the invert area; topographic verification of the actual position of the cutting head with respect to the metal ring.

e) Cutting head goes through the seal and places pressure on it.

f) Removal of the closing cover and subsequent transit of TBM shield up to reaching disassembly position. During this phase, particular attention must be devoted to segment backfill during the excavation

Below: **Figure 2 – The TBM encountered reinforced concrete before the shaft**



progress until reaching the grouted body so as to waterproof the area between the shield and the tail of the TBM.

Advantages and critical aspects for future consideration

The use of the equipment offers some important advantages the most significant of which is control of water inrushes. However there is an intermediate phase, between the breakthrough and pressurization of the seal, during which it is necessary to balance possible water inrushes from the hollow space between the shield and the soil. Another advantage is that it offers a reduction in soil consolidation from the surface. In the case of shafts or stations, to be crossed through as open zoes, in urban environments where accessible areas required for consolidation grouting may be considerably limited, the exploitation of such technology contributes to a significant reduction in the dimensions of grouted zone. In addition the equipment installed is entirely reusable in subsequent projects (apart from the shuttering pipe buried into the concrete template), which makes it possible to compare this solution with a grouted body from the economic point of view.

The experiences of the project team did however raise some critical aspects which, in our opinion, should be addressed in order to improve the efficiency and effectiveness of the method. Breakthrough debris is drawn through by the cutting head and may be removed, theoretically, only after pressure is exerted on the seal and the cover is opened. This gives rise to the following two drawbacks: the risk of damaging the seal because of contact with the debris (which is sometimes of considerable size) and the absence, between the seal and the cover, of hollow space sufficient to contain the quantity of debris accumulated and drawn by the cutting head. All the above makes it necessary to carry out very exacting operations in a hyperbaric environment; such operations mainly consisting in crushing and removing said excavation debris before making the shield go through the seal.

Above: The TBM's cap and the 2-seal ring as it enters the shaft

The cover is also equipped with water discharge outlets which are easily clogged by soil and mud debris and are made unserviceable in a very short time. This makes it impossible to remove, in a controlled manner, the water between the cover and excavation chamber, and to assess the consequent stabilisation of groundwater level, also with possible hyperbaric operations to be carried out. Increasing the number of water outlets and arranging the same more uniformly on the cover surface would improve the equipment serviceability.

Finally there is a need to remove peripheral tools before making the shield go through the seal which makes hyperbaric operations unavoidable, although such operations are of a limited duration and, therefore, are not considered as critical.

Top left: Working in the heart of Rome provided logistical challenges with its historic streets Below left & right: Once the cover is removed, particular attention must be paid to make sure the area between the shield and the tail of the TBM is waterproofed

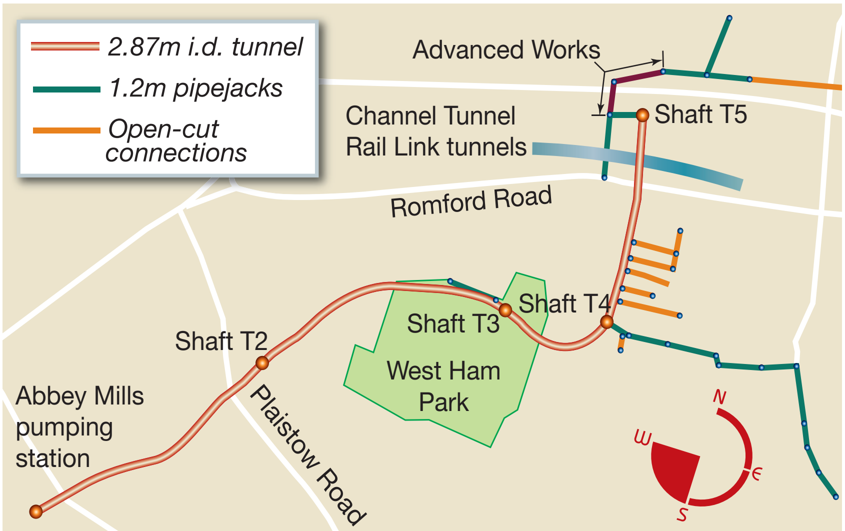
West Ham Flood Alleviation Scheme

For the May 2010 meeting of the British Tunnelling Society Steve Lousley of Southern Water, John Sweetnam of Aecom and Andrew Morgan and Tony Parsons of Costain made a presentation on the West Ham Flood Alleviation Scheme in London

The West Ham Flood Alleviation Scheme (FAS) serves a densely populated area of East London, approximately one mile (1.6km) south of the 2012 Olympic Park, and one mile (1.6km) north of West Ham's football ground at Upton Park. In the 19th century, a combined stormwater and sewage system was constructed through this area, gravity draining to Abbey Mills Pumping station where it was pumped into the Northern Outfall Sewer, running to Beckton treatment works to the east. In the intervening time, a rapid expansion of housing followed by a steady growth in the construction of extensions and hard-standing has over-stretched the system, and since the 1950s occasional flooding of streets or basements has occurred.

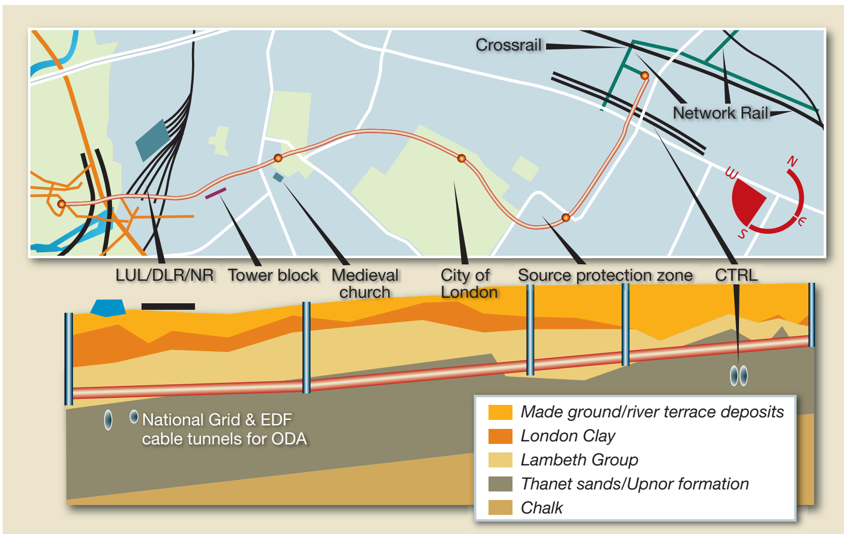
Under its commitment to The UK Water Regulator (OFWAT) Thames Water was required to take more than 5,500 properties out of flood risk by 31 March 2010, with more than 650 of these from the West Ham scheme. A number of options were considered including underground storage tanks to be used during overflow events, and tunnelled outfalls in a number of different directions to connect with adjacent systems. The selected option was to provide a new interceptor tunnel running lower than the existing system, pumping from the terminal shaft to the existing pumping station at Abbey Mills.

Aecom provided a reference design in preparation for a design and build tender under NEC3. Detailed studies and modelling of the existing system revealed that 22 interceptions onto the existing sewers were required, which ultimately resulted in the layout as shown in Figure 1. This included the construction of 3.3km of 2.87mID tunnel, 2.5km of 1.2mID microtunnels and 2km of open-cut.



Above: **Figure 1 – To update the West Ham FAS, Thames Water chose an interceptor tunnel, running lower than the existing system**

Below: **Figure 2 – Tunnel alignment and geology. The new tunnel route passes over and under a number of rail tunnels operating in and around London**



Above: **Building the inner caisson in T1**

The tunnels were to be driven in the Thanet Sands and the clays, sands and gravels of the Upnor formation at the base of the Lambeth Group, as shown in Figure 2. The route was to pass over the Olympic Development Authority (ODA) cable tunnels and the Channel Tunnel Rail Link (CTRL) tunnels, and beneath a number of London Underground (LU), Docklands Light Railway (DLR) and Network Rail lines, a tower block and a medieval church.

To enable the scheme, some 98 utility diversions were required, with 90 per cent of these let prior to award of the main contract. At T5 alone, the bill for the combined utility diversions exceeded GBP 500,000 (USD 757,000).

In March 2008, following a competitive tender process, Costain was appointed design and build contractor, with Halcrow as its designer. The team's objectives were safety, managing third parties and delivering a product that would last for 150 years by the 31 March 2010 deadline. Many of the sites would be within roads and adjacent to housing and businesses, inevitably causing significant local disruption. A substantial community relations programme was launched. More than 28,000 letters were put out in 20 languages, staffed drop-in centres were positioned at the sites, local functions were supported, schools were visited and a competition was held for local schoolchildren to decorate sections of site hoardings.

Below: **Contamination at Shaft T1 required shaft sink to be adapted**

Drive Shaft, T1

An initial site investigation borehole within the grounds of the Abbey Mills pumping station revealed the ground around T1 to be contaminated with benzenes and other aromatic hydrocarbons. Further investigation showed this to be limited to the Harwich and Channel Sands immediately below the London Clay. The source could not be identified but is thought to be from a former gasworks to the north. It was vital that the contaminants were prevented from reaching the lower aquifer, which is a source of drinking water nearby.

The shaft sinking methodology was therefore adapted:

- To cut off the contaminants, a secant pile cofferdam was driven to a level below the contamination and yet above the lower aquifer
- Dewatering wells were drilled into the Thanet Sands to relieve lower aquifer pressure. The discharge from these was sampled, demonstrating that no contaminants reached the lower aquifer either before or during construction
- A 15mID shaft was sunk to near the base of the secants by underpinning with the contaminated material within the shaft removed, requiring continuous monitoring, protective suits, forced ventilation respiratory protection and a strict occupational health regime
- A 12.5mID shaft was then constructed as a caisson from within the 15mID shaft.

The methodology worked well, though a number of secant piles were insufficiently vertical, causing some leakage into the cofferdam and requiring remedial grouting.

Main Tunnel Drive

The 2.87mID tunnel was driven with a new Lovat M132 EPB with a hydraulic drive and, unusually for a TBM of this size, a cable reeler. The large diameter screw conveyor can be changed for a belt, though the West Ham tunnels were all driven in EPB mode.

With the launch from T1 directly into contaminated ground, Costain proposed an elongated screw (from 14m to 20m) to take the discharge further away from the build area, thus allowing the creation of a well-ventilated zone for most of the workforce for most of the time. Continuous monitoring, the provision of personal and respiratory equipment and occupational health monitoring were continued for the first section of the drive.

The intermediate shafts were part-filled with foamed concrete to allow the TBM to mine straight through, though the TBM stuck while mining through T4 on a 200m radius curve and had to be partially dug out to relieve some thrust pressure.

The contract specification required settlement of the surface or structures to be less than 10mm, but the final settlement was generally no more than 4mm, demonstrating an effective face loss of one per cent. Only minimal movement occurred to the CTRL tunnels and there was no reported damage to utilities. The most severe property damage was only in the 'very minor' damage category.

Microtunnelling

The scheme included 18 microtunnel drives of varying lengths totalling 2.5km of 1.2mID pipes. These were intended to be driven by two TBMs, but at one point eight were employed. Two major problems occurred:

- The pipe following the TBM driving from MT10 to MT9 became stuck when the TBM was just 30m short of the reception shaft. Interjacks showed that the TBM would still move, but the pipe could not be advanced without major structural damage, indicating something had settled onto the tunnel.
- The TBM driving from MT4 to MT5 veered off course to such a degree that it could not be corrected. An additional shaft was sunk to recover the machine, and an additional machine was used to drive the remaining tunnel the other way.

It was not possible to sink an additional shaft to recover the MT10 to MT9 machine, and so a hand shield was used to drive a recovery tunnel the 30m from MT9. In preparation for this, permeation grouting was carried out above the tunnel, and ejector wells were installed beneath. Controls were introduced to minimise the vibration effect on the miners from using pneumatic tools, and thin 1.63mID steel liner plates were used to line the tunnel. These performed well, as long as they were built with good circularity. The 1.5m OD TBM was pulled through the temporary tunnel, which was then lined with 1.2mID concrete pipes.

Programme

Following early delays due to the contamination at Shaft T1, the team was constantly focused on the required "flows on" completion date of 31 March 2010. On the 2.87mID TBM, which broke through into T5 in mid December 2009, 24-hours a day, 7-days a week working was introduced. At peak, the TBM constructed 260m of tunnel in one week.

The recovery operations on the two microtunnelling machines were carried out just in time, with the last pipes installed in late March 2010.

The open-cut sections were completed without incident, the various connections made to the existing system and the shaft finishings installed. Mechanical and electrical installations included the pumps and pipework at T1.

Above: **Shaft T1, nearly complete**

Questions from the floor

Paul Monaghan - The City of London
Question - Why was the microtunnel driven off line?
Answer - This is not yet known and investigations are ongoing.

Bob Ibell - BTS Chairman
Question - How did Thames Water ensure that the known contamination does not in the future spread between the aquifiers through another party sinking a well.
Answer - To sink such a well would require the approval of Thames Water, and a condition of this approval would be that suitable processes were followed to prevent such cross-contamination, as at the West Ham scheme.

Rapporteur: Ken Spiby


tunnels & tunnelling
INTERNATIONAL
RESERVE YOUR COPY OF TUNNELS & TUNNELLING INTERNATIONAL
simply visit
www.tunnelsonline.info
SUBSCRIBE
TODAY!

Work, rocks 'n' rollercosters

"Growing up I always loved amusement parks and that's what got me in to doing engineering," says Nathan Ward, director of tunnelling projects at Paul C Rizzo Associates (Rizzo). However, his career path has ended up taking him below ground, rather than above it.

It was through his local theme park that Nathan became an engineer. "I never really had much guidance about college from my parents as neither of them went. But, there was an amusement park where I grew up called Kennywood Park, and they were putting in a new rollercoaster in 1991, called the Steel Phantom. I found out about the company that was designing it and I sent them a letter asking what I would have to do to design rollercoasters when I grew up. The designer, Ron Toomer, wrote me back and said to study engineering, either electrical and mechanical or civil, so I went to engineering school."

After graduating with a degree in mechanical engineering from the University of Pittsburgh in 2001, Nathan worked at several companies before deciding to do an MBA at Carnegie Mellon University's Tepper School of Business, which he completed last year. "That was a busy three years for me," he explains. As part of the programme, his chosen track, the path an MBA takes, focused on marketing.

He thinks that it was a mixture of experience from working at other organisations and his recently earned MBA that has led him to start, a year ago, in such a prolific position at such a young age. He explains that it's hard to find people with an engineering degree who also have good business sense.

"People who have an engineering background with even the slightest inkling of business sense should pursue that route. Really, to find someone who has an engineering degree, a business degree and a good personality is very tough."

And that background has been very useful, he says. "I think it's helpful to understand things from a technical standpoint of course, but you also have to be business savvy. You have to see the whole picture."

After working for a transportation company prior to starting his MBA, Nathan was familiar with tunnelling, from the other side, he says, "putting together a rail system, how do you get a train from point A to point B." But it wasn't until he started his job with Rizzo, working out of its Pittsburgh-based corporate headquarters, that he really started to get into the tunnelling industry.

At the moment, Rizzo, an engineering and consulting company, is involved with several projects in the US, including the North Shore Connector project in Pittsburgh, and it also has a crew in South America. "I've been lucky enough to take a trip there," says Nathan. "They're at very high altitudes, 4,000m above sea level. They're battling the elements, doing pretty advanced geo-technical investigations at places where probably people shouldn't even be. It's great that there's such a scope of projects going on at the moment."

While he enjoys working on tunnelling projects, he says one career highlight has been at a previous job where he had to try to convince people certain ideas could work. "Sometimes people don't fully understand something until they see it, so you have to just do it," he explains.

"I worked at Bombardier for a few years doing mechanical design work. We did a project in Miami, the Downtown People Mover, it's like a driverless subway train but it's on an elevated cement platform. We had an opportunity to incorporate new technologies that hadn't been incorporated before."

While he admits there were moments when the project manager didn't always appreciate the team's ideas because of conflicts like timing and planning approval: "At the end of the day it ended up being a really successful project and the client was thrilled."

He says, "it's something I'm very proud to have been involved with. It's something where I can point at things and say, 'that was my idea.'"

"That's why people go into engineering. We don't have inventors anymore. At least no one calls them that. Thomas Edison, he was an inventor, and what he was doing was engineering."

Outside of work, Nathan enjoys playing music with his band and leading his son's Cub Scout group. Having been a scout when he was a boy, he jumped at the chance to become a leader when his son was keen to join. While the boys are too young to go on long trails they do study for their badges, attend summer camp for a week and go on special trips. One place that Nathan has enjoyed taking them to is a local attraction called Laurel Caverns, the largest cave in Pennsylvania.

It's a geological anomaly as it is formed of a low calcium limestone made up of 70 per cent silica grains cemented together with 30 per cent calcium carbonate and a small amount of iron oxide. As it was also formed in an area of folded and fractured rock, the cave tilts fifteen degrees, resulting in many steep passageways. "They learn a lot about geology here, which is fascinating for someone who understands these concepts," he says.

What about a theme park based on tunnelling? "To have the world's first subterranean theme park would be really cool," he says.

Business directory

To advertise on these pages call Tom Willard on: +44 (0)20 7936 6843 or email twillard@tunnelsonline.info

Product marketplace

BAUMA LAUNCH FOR WORLD'S SMALLEST HYDRODEMOLITION UNIT.

Conjet AB is extending its comprehensive range of leading hydrodemolition equipment with the launch of the latest revolutionary high-pressure hydrodemolition Conjet 'Nalta' Jetframe 101. Conjet 'Nalta' is the world's smallest and lightest hydrodemolition unit. It replaces and robotises the dangerous and far less productive hand lancing method of hydrodemolition, as the 'Nalta' operator remotely controls all functions of the Jetframe 101 at a safe distance from the working area.

The Conjet 'Nalta' Jetframe is very flexible and versatile as it mounts, climbs and operates on standard scaffold tubes, and as there are no electrical sensors it can also operate under water. All components are small, light, easy to carry and position. The cutting head weighs 14 kg, the feed beam section 6 kg and each hydraulically controlled step units, which are fixed to each end of the feed beam and automatically climb up and down standard scaffold tubes, weigh 9 kg each. The trolley mounted hydraulic control unit weighs 90kg.

Safety has been paramount in the design of the Conjet 'Nalta'. ("Nalta" is a colloquial expression from Vilhelmina in Lappland in northern Sweden meaning something very small.) 'Nalta' operators do not need the 'spaceman type' bulky and heavily protective clothing that is vital when using awkward and cumbersome hand held lances.

Conjet AB
T: +46-(0) 8-5565-2240 **F:** +46-(0) 8-5565-2260
E: lars.nilsson@conjet.com **W:** www.conjet.com

BAUMA LAUNCH FOR NEW CONJET ROBOT 365 MPA

The leading Swedish hydrodemolition equipment manufacturer Conjet AB is launching its latest high-pressure water jetting Conjet 365 MPA robot, with its versatile robotic multi-purpose arm (MPA), as a direct replacement for the renowned and successful Conjet Robot 364 MPA.

The new Conjet Robot 365 MPA can remove concrete from numerous surfaces, including above and underneath the robot with minimal set up time. Its main use is for the removal of concrete in hydrodemolition applications, but can also be used for removing rust and paint from ships' hulls and other similar structures. Due to its rigid design and improved multi-purpose arm, which reaches up to 6.4m above the robot and 3.3 m down the side, the new Robot 365 MPA can operate with a reaction force up to 2000N, which is equivalent to the force of a water jet generated by a 550kW (700 HP) high-pressure water pump.

The Robot 365 is also available with a Heavy Duty Arm (HDA) which is capable of handling a reaction force of 3000N generated by a larger 750kW (1000HP) pump. The Robot 365 has outstanding stability and can withstand these high reaction forces while safely operating the feed beam with its jetting lance in any position. In addition Robot 365 can be fitted with an optional tower mast attachment on its front or side and is capable of reaching down and operating 6m below the robot.

Conjet AB
T: +46-(0) 8-5565-2240 **F:** +46-(0) 8-5565-2260
E: lars.nilsson@conjet.com **W:** www.conjet.com

BAUMA LAUNCH FOR NEW CONJET ROBOT 324

The leading Swedish hydrodemolition equipment manufacturer Conjet AB is launching its latest high-pressure water jetting Conjet Robot 324, as a direct replacement for the renowned and successful Conjet Robot 322.

The Conjet Robot 324 is the most compact, versatile and cost effective Robot for hydrodemolition on the market. With its robotic arm the Robot 324 can work on horizontal and vertical surfaces as well as inside tubes and circular tunnels. The small Robot 324 opens up new areas for mechanising concrete removal with superior bonding for fresh concrete, due to the absence of micro cracks. It replaces inefficient hand lancing and jack hammering and other percussive methods.

The Conjet Robot 324, weighing 1100kg, has been developed to work in confined spaces and areas inaccessible to larger hydrodemolition machines. The Robot 324 passes through a 900mm opening and, coupled with its exceptional manoeuvrability, makes it the perfect machine for operating in confined spaces, like small tunnels, tubes and inside concrete box girder bridges. Due to its low weight, which is evenly distributed by the rubber tracks, the Robot 324 can be operated safely and easily on access platforms and scaffoldings.

Conjet AB
T: +46-(0) 8-5565-2240 **F:** +46-(0) 8-5565-2260
E: lars.nilsson@conjet.com **W:** www.conjet.com

Business directory

Product marketplace

BAUMA LAUNCH FOR CONJET BLUETOOTH CONNECTION

The leading Swedish hydrodemolition equipment manufacturer Conjet AB will use Bauma to launch its new and patented Bluetooth communication system to control functions between Robots, Jetframes, and their respective Powerpacks.

The new system eliminates the physical cable connection between Conjet Robots, Jetframes and Powerpacks. Instead the Bluetooth communication uses a master controller unit connected to the Robot or Computer Control Unit (CCU) and a separate slave unit connected to the Powerpack. The two separate units communicate by Bluetooth Class 1 and to guarantee safety and integrity between the two they are initially 'paired' together at the factory. This is to ensure the units only communicate with each other and eliminate the risk of the Powerpack being controlled and corrupted by similar Bluetooth devices, such as mobile phones.

The Bluetooth communication has a distance limit of approximately 100 m. If the master and Powerpack slave units are further apart an extension cable can be used to place the slave unit closer to the Robot master.

The optional Conjet Bluetooth wireless connection can be factory fitted or retro fitted on site for use on all Robots and CCUs.

Conjet AB
T: +46-(0) 8-5565-2240
F: +46-(0) 8-5565-2260
E: lars.nilsson@conjet.com
W: www.conjet.com

NEW COMPACT HÄGGLOADER FOR 7 M2 CONSTRUCTION AND MINING TUNNELS

1st three 7HR-B Häggloaders ordered for Leighton-LNS JV contract on the Hong Kong Area Treatment Scheme (HATS) sewage conveyance system

Compact digging arm loader from GIA has been designed for 7 m² cross-sectional tunnels and offers the option of electric or diesel power.

A new compact, rubber-tyred digging arm loader from Sweden's GIA Industri AB, the 7HR and 7HR-B Häggloader, has been introduced for use in construction and mining tunnels and drifts with a cross section area of just 7 m².

Designed for operating in tunnels with a width of 2500 mm and a height of 2500 mm, the wheeled loader has a loading capacity of 2.5 m³/m.

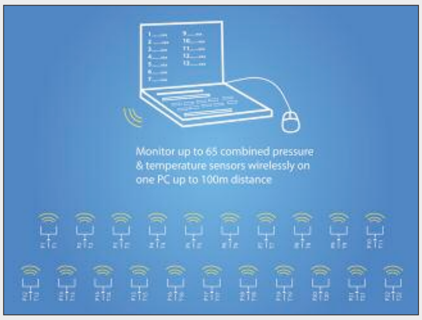
The 7HR features two unique digging arm systems – digging arms or rotating backhoe - to load the spoil/muck from the tunnel face directly onto the Häggloader's conveyor, which fills the haulage vehicle with a constant supply.

The conveyor can be raised and lowered to suit the loading height of the different haulage vehicles.

The backhoe version can also be equipped with a hammer for scaling the blasted profile.

The option of electric or diesel power source is offered for the Häggloader's hydraulic system and for tramming and transportation.

T: +46 24079700
F: +46 24079725
E: info@gia.se
W: www.gia.se



GROUND BREAKING WIRELESS PRESSURE TRANSDUCER SYSTEM LAUNCHED

Hydrotechnik is set to revolutionise the wireless pressure and temperature sensing market with the innovative, low cost HT-Wcom system that can monitor up to 65 sensors at once on one PC. Sensors are self-powered and transmit both pressure and temperature readings.

The HT-Wcom system allows monitoring and alarm functioning of up to 65 pressure transducers located within a 100m radius. The sensors of the HT-Wcom System connect remotely to 1 PC with no additional interfaces required. Sensors are self-powered and send pressure and temperature readings.

With Condition Monitoring now more than ever an essential process to enable systems to run safely and efficiently, this innovative, discreet, low-cost system will transform the wireless pressure and temperature sensing market.

The pressure sensors are self-contained, compact, battery powered IP67 units with a number of pressure ranges available. Standard sensors are 0 to 500 bar but they can also be manufactured from -1 up to 1000 bar.

The beauty of the new system is that just 1 PC can monitor up to 65 remote sensors directly, keeping the cost of the system low.

The software that monitors the sensors can be configured to show individual plant or system schematics with graphical sensor location to help identify problem areas.

Contact Chris Banks at Hydrotechnik:
chris@hydrotechnik.co.uk
Tel: +44 (0)1159 003 550 **Fax:** +44 (0)1159 705 597

Business directory

To advertise on these pages call Tom Willard on: +44 (0)20 7936 6843 or email twillard@tunnelsonline.info

EQUIPMENT

EQUIPMENT FOR MINING AND TUNNELLING SINCE 1884

GIA www.gia.se

FABRICATION

TRANSFORGE UK LTD

Tunnel Steelwork Specialists

Cable & Pipe Brackets and Walkways

Sleepers and Accessories

+ 44 (0) 1572 787 504

info@transforge.co.uk

GROUND CONTROL

hw hoelscher dewatering

· dewatering
· groundwater control
· water treatment

www.hw-dewatering.com

DYWIDAG-SYSTEMS INTERNATIONAL DSI

ALWAG SYSTEMS

GROUND CONTROL SOLUTIONS

DSI UNDERGROUND SYSTEMS INC.

www.dsi-tunneling.com

MICROTUNNELLING

WHEN THE GOING GETS TOUGH...

...Iseki comes smiling through!

Microtunnelling equipment - hire or sale

ISEKI MICROTUNNELLING

Iseki Microtunnelling Wellingborough UK
+44(0)1234 781166 www.isekimicro.com

PIPES & COUPLINGS

ALVENIUS®

Quick connected steel pipe system

P.O. Box 550
SE-631 07 ESKILSTUNA, SWEDEN
Tel: +46 16 16 65 00
Fax: +46 16 12 26 34

RAIL & ROLLING STOCK

Clayton

World Leading
Locomotives & Haulage Solutions...

...for Mining, Tunnelling & Surface Transport

Clayton Equipment Ltd
www.claytonequipment.co.uk Tel: +44 (0) 870 112 9191

RAIL & ROLLING STOCK

VALENTE

www.valente.it info@valente.it

MASCHINEN- UND STAHLBAU MSD DRESDEN

NIEDERLASSUNG DER HERRENKNECHT AKTIENGESELLSCHAFT

Your partner for special solutions in the tunnelling sector.

Phone: +49 (351) 42 34-0
Fax: +49 (351) 42 34-103
E-Mail: info@msd-dresden.de
www.msd-dresden.de

SEGMENT FITTINGS

TTC

TECHNICAL TUNNELLING COMPONENTS

PLASTIC COMPONENTS FOR SEGMENT CONNECTION
BUILDING AND GROUTING SYSTEMS

WWW.TTCLTD.ORG
+44(0)1455 234401

SURVEYING & MONITORING

VMT
www.vmt-gmbh.de

CODEL
tunnel atmosphere monitors

t : +44 (0) 1629 814 351
f : +44 (0) 8700 566 307
e : sales@codel.co.uk

www.codel.co.uk

TBM'S & PIPE JACKING

WÜWA BAU

Tunnelling
Soil Injections
Boring
Civil engineering

www.tunnelvortrieb.de

VENTILATION

SCHAUENBURG
TUNNEL-VENTILATION GMBH

Flexible Ventilation Ducting

www.tunnel-ventilation.de
Phone: +49 208 8827610
Fax: +49 208 8827615

TUNNELLING SUPPLIES

TA Tunnelling Accessories

EPDM GASKETS
PLASTIC SEGMENT FITTINGS
FOAMS & POLYMERS
HYDROPHYLIC RUBBER
BOLTS
PACKERS
LIFTING EQUIPMENT

BULLFLEX
SEALING STRIPS
SECONDARY SEALS
TBM LAUNCH SEALS
LUBRICANTS
ROLLING STOCK

+44 (0) 1424 854112
info@tunnellingaccessories.co.uk
www.tunnellingaccessories.co.uk

WATERPROOFING

ABG
ENVIRONMENTAL GEOSYNTHETICS

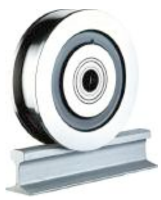
CAVIDRAIN

Waterproofing & Drainage for Tunnel Walls & Invert

T: +44 (0) 1484 852250
F: +44 (0) 1484 354825
E: export@abgltd.com
www.abgltd.com

WHEELS

BRAUER®



Brauer Limited.
Dawson Road,
Mount Farm,
Milton Keynes,
MK1 1JP.

t: +44 (0)1908 374022
f: +44 (0)1908 641628
e: sales@brauer.co.uk
w: www.brauer.co.uk

RECRUITMENT

Website: www.ayesa.com Branch Office: Gurgaon, India ayesa

AYESA main line of business is into conducting Engineering and Architectural Surveys and projects in the field of transportation (i.e railways, highways, airports etc), buildings (commercial, residential, hospitals, metro stations, airports, railway stations etc), water management, industrial plants etc. We are well equipped to carry out all the works, right from the commencement of proposing of ideas, feasibility studies, development and management to the commissioning of the Work.

Job Description – Tunnel design Engineer:
- His scope of work broadly includes overall control of the design of the tunnel (finalization and adoption of tunnelling technique and method)
- He should be well conversant with the prevalent standard codes and special publications
- He should be well versed in reading and understanding of various drawings, technical reports, various geotechnical and soil related mappings and various surveys (Topographical, bathymetric etc.) and related design software, like Unwedge programme, FLAC 3D programme, Slide programme and related calculations and modelling
- The candidate should have a relevant experience with NATM, TBM and other prevalent tunnelling methods

Desired Experience:
- More than 12 years of experience, specifically in tunnel designing
- Person should have rich experience in designing of tunnel with electrification, ventilation, illumination, safety and communication systems
- Indian national having experience on international projects will be given an advantage

Required qualification:
- ME/Mtech/PHD in the relevant field

Location:
- India. Position is not limited to the site, candidate will be required to travel anywhere within the country

Please apply with your updated resume to delhi@ayesa.com Tel: +919873106063

EX-TUNNELLER & MINER

seeking work anywhere in the world

Certificate in Specialised Plant & Machinery Operations, also Loco trained.

Contact: **07707 658866** | **rd.gayle@yahoo.co.uk**

Hunter Personnel

Specialists in Tunnelling, Civils and Construction Recruitment.

Ref: PN4168	**Senior Tunnel Engineer,** London, UK
Ref: PN4158	**Lead Planner,** South East Asia
Ref: PN4149	**Tunnel Design Engineer,** Sussex, UK
Ref: PN4131	**Senior Tunnel Engineer,** Drill & Blast, Malaysia
Ref: PN4109	**Senior Tunnel Engineer,** India

Tel: +44 (0) 1202 298322
Email: tt@hunterpersonnel.com

www.hunterpersonnel.com

SAVILE LLOYD

International Recruitment Services

Savile Lloyd is the international division of the Setsquare Group. Since 1997 we have provided professionals to the construction industry, with particular emphasis on the civil engineering sectors including highways, infrastructure, heavy civil and tunnelling projects in the Middle East, North Africa and Far East.

Our client is a major international contractor with extensive involvement in mining and tunnelling projects in Asia and Australia.

For operations in the Far East they require:

Tunnel Engineering Manager — Hong Kong

A degree in Civil Engineering, over 20 years experience in relevant projects with emphasis on drill & blast and TBM tunnel projects.

Grouting Engineer — Hong Kong

Expertise in high pressure grouting (up to 100 bar), experience of Microfine Cement and Colloidal Silica is a must.

Senior Tunnelling Engineer — Hong Kong

A degree in Civil/Geotechnical Engineering plus at least 5 years relevant experience in metro projects.

Rail Consultant — Thailand

Over 20 years experience in rail projects including rehabilitation works. Extensive knowledge of tendering, method statements and technical submissions required. This position is a short term contract (two months).

For full details please contact Edward Phelps on 00 44 1823 270917 or email your CV to edward.phelps@savilelloyd.com

www.savilelloyd.com

Global Tunnelling Experts.

Bringing the best together.

Global Tunnelling Experts is your teamwork partner for the best human resource solutions on your tunnel construction site. We supply personnel for all jobs throughout all the construction phases – including operational job profiles for all aspects of mechanized tunnelling operations and the equipment they involve. **Choose the right experts and contact us now.**

Global Tunnelling Experts
+31 (0) 10 266 94 44
clients@global-tunnelling-experts.com
www.global-tunnelling-experts.com
The Netherlands I Great Britain I Cyprus

Global Tunnelling Experts

BTS corporate members

To advertise on this page call Tom Willard on: +44 (0)20 7936 6843 or email twillard@tunnelsonline.info

British Tunnelling Society

This is not the full list of British Tunnelling Society Corporate Members | To see a full list of all members visit: **www.britishtunnelling.org.uk**
To become a British Tunnelling Society Corporate Member please contact: **bts@britishtunnelling.org.uk**

dates & events

19-23 JUNE 2010
North American Tunneling Conference, Portland USA
The 2010 NAT will be held at the Marriott Downtown Waterfront Hotel in Portland, Oregon. Conference and exhibition information and registration is available on the SME web site. Contact: Society for Mining, Metallurgy and Exploration (SME); web: www.smenet.org.

5 - 9 JULY 2010
BTS Tunnel Design and Construction Course
The BTS Course for 2010 has been modelled to address the ever changing face of the tunnelling industry and to focus on the project life from inception through to construction.
tel:+44 (0)20 8774 2252
fax:+44 (0)20 8681 5706

21 - 22 JULY 2010
13th Annual Queensland Transport Infrastructure Summit, Brisbane Australia
Now in its 13th year, the Queensland Transport Infrastructure Summit has developed into a pivotal forum for industry, transport users and government representatives to exchange open and practical discussions on current projects and future planning developments.
Telephone +61 2 9080 4307
Fax +61 2 9290 3844
E-Mail: registration(at)informa.com.au

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

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

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

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

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

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

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

1 - 3 MARCH 2011
International conference and exhibition on tunnelling and trenchless technology at the Grand Dorsett Subang Hotel, Selangor, Malaysia
The 2011 conference orgaised by the Tunnelling & Underground Space Technical Division (TUSTD) at The Institution of Engineers, Malaysia (IEM), will focus on tunnelling in South East Asia, future challenges and management of safety and risk. Contact: Conference Secretariat, Tunnelling and Underground Space Technical Division, The Institution of Engineers, Malaysia Bangunan Ingenieur, Lots 60/62, Jalan 62/4 P.O.Box 223 (Jalan Sultan), 46720 Petaling Jaya, Selangor, Malaysia; Tel: +(603) 7968-4001 / 4002; Fax: +(603) 7957-7678; Email: Tunnel2011@iem.org.my Website: www.iem.org.my

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

BRITISH TUNNELLING SOCIETY

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

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

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

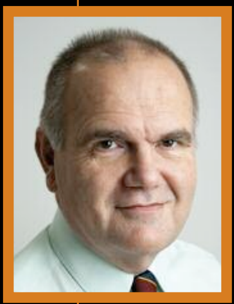
16 DECEMBER 2010: **Baggage tunnel design and construction at Heathrow Airport**
Andrew Stephenson of BAA, Enrique Blanco of Ferrovial and Athur Darby of Mott macDonald give details on the challenges of constructing the tunnel under one of the world's busiest airports. ICE, 5.30pm for 6pm start.

A DATE TO REMEMBER...

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

contacts

Jon Young



Maurice Jones

Shelly Palmer

EDITORIAL

EDITOR
Jon Young
Tel: +44 20 7936 6826
Email: jyoung@tunnelsonline.info

TECHNICAL EDITOR
Maurice Jones
Tel: +44 20 7936 6827
Email: mjones@tunnelsonline.info

NEWS EDITOR
Kris Mole
Tel: +44 20 7936 6828
Email: kmole@tunnelsonline.info

FEATURES EDITOR
Nicole Robinson
Tel: +44 20 7936 6802
Email: nrobinson@tunnelsonline.info

EDITORIAL SECREATARY
Tasha Denney
Tel: +44 20 8269 7833
Email: ndenney@tunnelsonline.info

REGULAR CONTRIBUTORS
Adrian Greeman, Bernadette Redfern, Patrick Reynolds

PRODUCTION & DESIGN

DESIGNERS
Natalie Kyne, Dan Becker

TECHNICAL ILLUSTRATOR
Nick Stenning

PUBLISHING MANAGER
Dan Gardiner

PRODUCTION CONTROLLER
Loraine Lee
Tel: +44 20 8269 7799 Fax: +44 20 8269 7840
Email: llee@progressivemediagroup.com

ADVERTISING

HEAD OF SALES
Shelly Palmer
Tel: +44 20 7936 6848
Email: spalmer@tunnelsonline.info

EUROPEAN SALES
Randolf Krings
Tel: +49 611 5324 416 Fax: +49 611 5324 519
Email: t&t@emcmedia.de

NORTH AMERICAN SALES
Clive Bullard
Tel: +1 845 231 0846
Email: cbullard@tunnelsonline.info

DISPLAY SALES
James Snowdon
Tel: +44 20 7936 6942
Email: jsnowdon@tunnelsonline.info

CLASSIFIED AND RECRUITMENT
Tom Willard
Tel: +44 20 7936 6843
Email: twillard@tunnelsonline.info

ITALIAN SALES
Ediconsult
Tel: +39 02 477 10036 Fax: +39 02 477 11360
Email: milano@ediconsult.com

HEAD OFFICE: **World Market Intelligence**
John Carpenter House, 7 Carmelite Street,
London EC4Y 0BS, UK
WEB ADDRESS: www.tunnelsonline.info
EMAIL: editor@tunnelsonline.info
TEL: +44 20 7936 6826
FAX: +44 20 7936 6813

HOW TO SUBSCRIBE

Subscription prices for 12 months

Mailed anywhere in Europe €255, USA & Canada $251, UK only £104, Rest of the world $307.

Send subscription and back issue queries to Tunnels & Tunnelling Customer Services:
Email: cs@progressivemediagroup.com

Subscription Hotline:
Tel: +44 (0) 845 155 1845 (local rate)
Fax: +44 (0) 208 269 7277
Email: subscriptions@progressivemediagroup.com
Tunnels & Tunnelling Subscriptions,
World Market Intelligence,
Progressive House, 2 Maidstone Road,
Foots Cray, Sidcup, DA14 5HZ.
Subscribe online at www.getthatmag.com

HOW TO GET REPRINTS

The contents of T&T is subject to copyright. However, if you would like to obtain copies of an article for marketing purposes high-quality reprints can be supplied to your specification. Please contact the advertising team for full details of this service.

Tunnels & Tunnelling International is printed at Stephens & George Print Group, Merthyr Tydfil.

Tunnels & Tunnelling International ISSN number 0041-414X is published monthly for US$226 a year by World Market Intelligence Ltd (www.worldmarketintelligence.com), a Progressive Media Group company, John Carpenter House, 7 Carmelite Street, London EC4Y 0BS, UK. Periodicals postage paid at Rahway, NJ.
POSTMASTER: send address corrections to Tunnels & Tunnelling International c/o BTB Mailflight Ltd, 365 Blair Rd, Avenel, NJ 07001. US agent: BTB Mailflight Ltd, 365 Blair Rd, Avenel, NJ 07001.