JUNE 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON REFURBISHMENT

The refurbishment works planned for London's Victoria Station are examined

TRENCHLESS TECHNOLOGY

T&TI looks at recent developments in trenchless installation and replacement

SWITZERLAND: MINIMIZING FLOOD DANGER.

Lake Thun in the Bernese Oberland repeatedly bursts its banks due to strong rains and melting snow. The region was hit by two heavy floods in 1999 and 2005 respectively. Now, a discharge tunnel is built to provide relief. Up to 115 cubic meters of water per second can be discharged through the 1,169 meter long tunnel from the lake into the Aare river.

There is not much room to maneuver in the launch and target shafts of the tunnel: the Herrenknecht Mixshield S-398 (∅ 6.27 meters) must be assembled on an area of only 16x 32 meters and later dismantled in an even smaller space. However, this has no effect on the machine's performance: with top daily performances of almost 20 meters, it reached its target under the professional direction of the Consortium, ahead of schedule on April 15, 2008. The tunnel will be put into operation at the end of 2009, making the danger of flooding a thing of the past.

THUN | SWITZERLAND

PROJECT DATA	CONTRACTOR
S-398, Mixshield Diameter: 6,270mm Driving power: 330kW Tunnel length: 1,169m Geology: broken rock, sand, silt	Arbeitsgemeinschaft Hochwasserentlastungsstollen Thun, PraderLosinger AG, Walo Bertschinger AG

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

www.herrenknecht.com

HERRENKNECHT
Tunnelling Systems

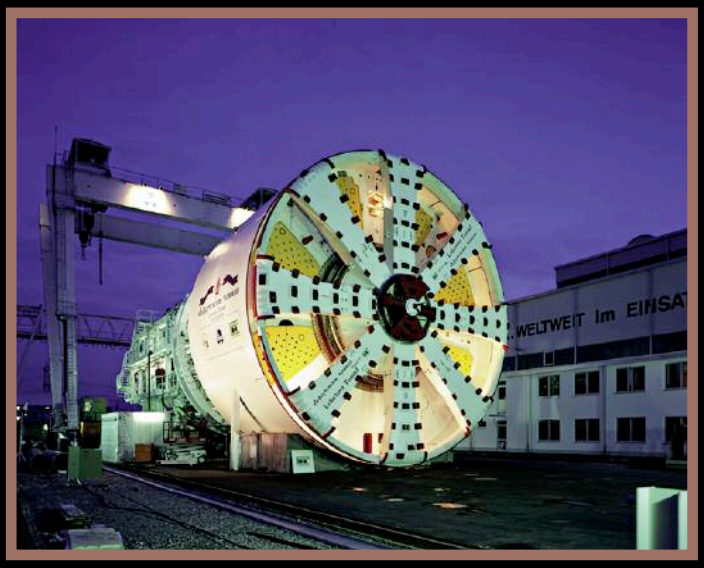
Contents

FRONT COVER:
A convergence support system being installed in a troublesome section of squeezing ground on the Sedrun section of the Gotthard Tunnel (p40).

WEB ADDRESS
www.tunnelsonline.info

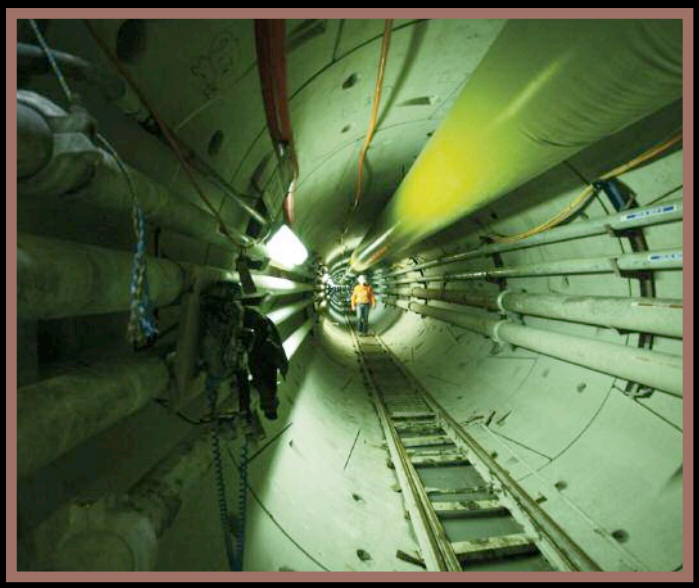
CONVERSIONS
US$1.00
€0.64
£0.51

REFURBISHMENT FOCUS



31

The 14.2m diameter Lefortovo Mixshield ready for shipping

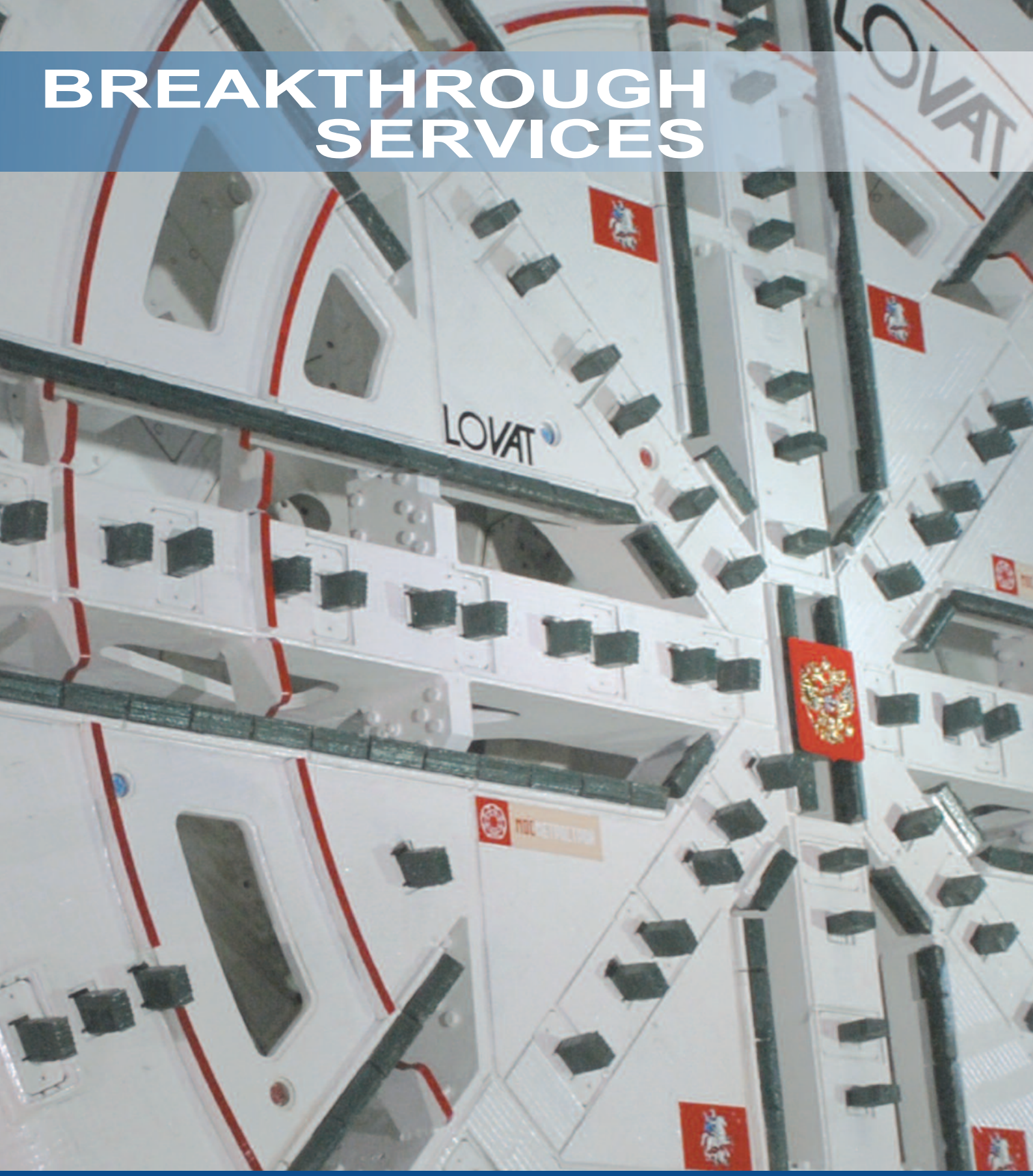


TRENCHLESS TECHNOLOGY

25

A view down one of Australia's Gold Coast Desalination Project tunnels

BREAKTHROUGH SERVICES



Providing our clients with a complete support system, from conception to completion

WWW.LOVAT.COM

PROJECT MANAGEMENT
OPERATOR TRAINING
TUNNELLING TECHNICAL SERVICES
SITE MANAGEMENT SERVICES

LOVAT
BREAKTHROUGH TECHNOLOGY
For the Tunnelling Industry
Registered **ISO9000:2000** Certificate:008106

Variety is the spice...

It's going to be quite an undertaking, the extensive renovation works planned to relieve passenger congestion at Victoria Station, one of London's most famous and busiest transport hubs (p16). The designs make it look more like a giant rabbit warren waiting to be unveiled on completion under the thriving, and often overcrowded area of the capital's west.

The engineering intricacies involved, in some pretty tight spaces, will throw up a host of challenges specific to the project, and, as with most schemes undertaken these days, the designers and contractors will doubtless step up and make it happen.

It's a refreshing reminder of the degree of variation open to the world of underground civils, and a good one to re-iterate that tunnelling isn't just the construction of long holes in the ground, albeit the substantial meat and drink of the industry.

In *T&TI* we have reported on a host of alternative uses for underground space. There have been wine caverns in California, gas storage caverns in Scandinavia, seed storage facilities in the arctic, underground museums in Japan, bank vault access and penitentiary egress tunnels the world over (although not condoned in any way shape or form by *T&TI*, the BTS, or its editorial board as sound pieces of civil engineering!), nuclear storage networks in the US, underground pieces of artwork in the Canary Islands, to name but a few. The list could go on and on, and does.

But then thinking about it, there is a massive variation in the works involved purely in more traditional type of tunnel projects i.e, TBM, drill and blast, NATM, perforex, immersed tube. Just within TBMs we have EPBMs, Mixshields, slurry shields, hard rock grippers, DSU's etc, to suit a range of diameters and a host of varying geologies. And on top of this, the works are on-going the world over and it's you with the opportunity to get to the sorts of places most people only dream about.

So when that inevitable feeling of career despondency kicks in, as it does with most people in all walks of life, just ask some poor soul stuck behind a desk day-in-day-out what the future holds for them. For the tunnelling engineer, it could be a lot worse.

Finally, just a quick note to say that with the recent company change comes the inevitable new email addresses. So, from now, any correspondence to the editor, positive or negative, should be sent to: tthomas@tunnelsonline.info

I look forward to hearing from you…

Tris Thomas

COMPANIES IN THIS ISSUE

Seli completes Passirio bore

The Seli joint venture has completed tunnel excavation on the Passirio (Val Passiria) small hydro project in Italy with the breakthrough of the 3.7m diameter double shield universal (DSU) TBM for the headrace drive.

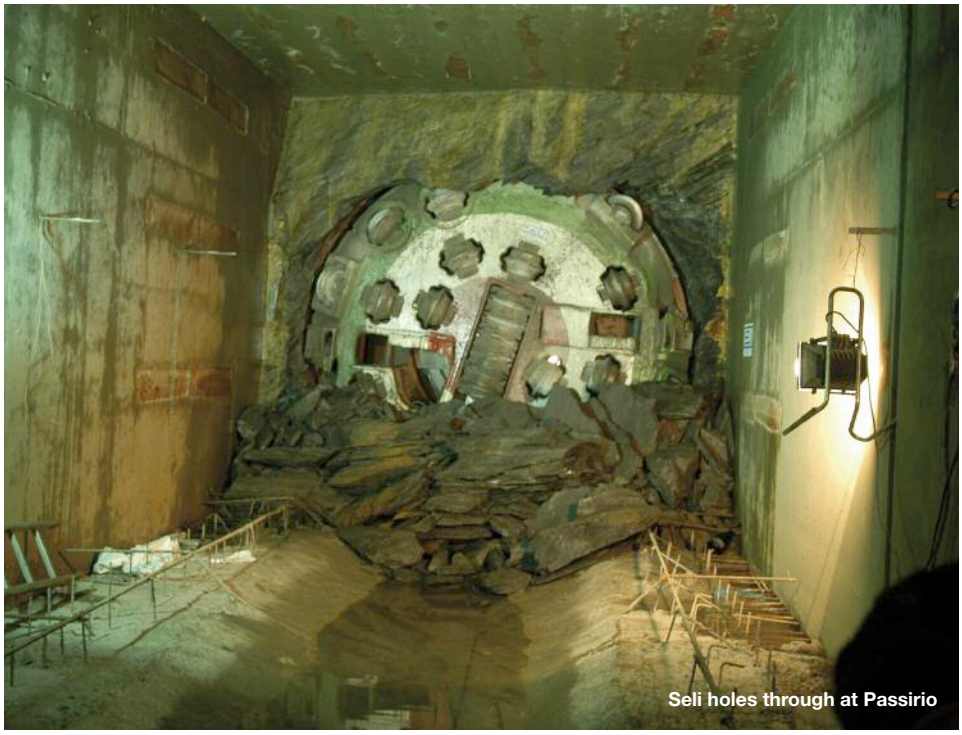
Seli modified a Wirth double shield for the 5,885m long headrace tunnel excavation, which took 12 months to complete. Average advance during the bore was 500m per month, though inflows up to 400 l/s slowed progress at times.

Geology along the alignment is comprised of gneiss and micaschist. The TBM was fitted with 17" cutters, has a maximum cutterhead thrust of 5,280kN and total drive power of 1,120kW.

The headrace – which was the only TBM-driven tunnel on the project – has an internal diameter of 3.1m. The segmental lining (4 trapezoidal) is 200mm thick and rings are 1.1m long.

Seli and local JV partner Edilmac were awarded a two-year contract for the works in the third quarter of 2006, valued at US$30.4M in 2006 prices, US$36.6M in current prices. The client is Enerpass AG.

Other tunnelling works on the project included 113m and 51m long access tunnels, excavated by drill and blast. The JV also excavated a 48m deep shaft by raise bore, which was also lined with concrete segments.



Seli holes through at Passirio

Subsidence at Singapore's Circle Line

Tunnelling works were stopped late last month on part of the C855 section of the Circle Line extension in Singapore to investigate subsidence at the ground surface over a slurry TBM and perform extra grouting works.

Following the rapid backfilling of the hole that opened up in the Cornwall Gardens road, works were continuing to restore the local area following some utility disruption to houses. The location of the hole is between the stations being built at Farrer and Holland Village.

A hole that was 3m deep and measured 7m by 8m had formed above the location of the TBM in the early hours of Saturday, 24 May. Tunnelling work at the location was stopped to enable inspection and further grouting works.

The 6.6m diameter TBM was on the final, northbound leg of its drives, on the section from Holland Village station to Farrer station where it will terminate, when the incident happened. The contractor on C855 is the joint venture of Woh Hup, Shanghai Tunnel Engineering and Alpine Mayreder (WSA).

The client, Land Transport Authority (LTA), anticipated that the damaged road would be re-opened by about the end of May, but progress details were not available as T&TI went to press. It added that the incident was not expected to affect the overall progress of construction work on stage 4 of the Circle Line, which is to be completed from 2009 onwards.

Four TBMs from Herrenknecht are being used by the JV on the contract – two EPBMs and two Mixshields. Geology on the C855 contract section comprises loam, alluvium, sand and weathered granite.

On the adjacent, unrelated contract C854, contractor Taisei has completed the refurbishment of two 6.6m diameter slurry Kawasaki TBMs and re-launched them from Botanic Gardens station on southbound drives to Farrer station, where they will also terminate. The other pair of machines on the contract have been stripped out and track and M&E fit-out is underway (*T&TI*, March 2008, p6).

Turkey Creek flood sinks tunnel workers

Flood water in Turkey Creek tunnel in Kansas City, Kansas, recently swamped a boat holding four workers who were left fighting for lives until a rescue was completed by emergency services.

The workers were trapped by the rising floodwater when attending to flood control measures in the almost 400m long tunnel, which was recently restored as part of a US$92M flood control scheme. The tunnel links Turkey Creek with Kansas River, and they routinely travel through by boat.

But on their way to place sandbags on a dam inside the tunnel to hold back flows from the Kansas River, in late April, the rising waters inundated and capsized the boat. One worker, Cliff Keppen, a labourer for contractor Merco/Obayashi, told local media at the time of the rescue that the incident occurred in almost 3m depth of water.

Two workers made their way to an overflow pipe up the tunnel wall from where they managed to crawl along its length to the tunnel mouth. Keppen swam to a pipe on the tunnel wall where he was joined by the fourth worker, from where they were rescued after being in the water for more than one hour by members of the fire department in an inflatable boat.

One of the firemen commented on the difficulty of the environment being added to by the noise from the floodwater and the darkness in tunnel. Reports equated 25mm of rainfall in the area as corresponding to a rise of approximately 1.25m in the water depth.

First Yangtze giant holes through

The first of the pair of 15.43m diameter TBMs – the world's largest – excavating road tunnels below the Yangtze river, at Changxing Island near Shanghai, has holed through some months ahead of schedule.

Excavation of the twin tunnels commenced in September 2006 and by January last year both of Herrenknecht's Mixshields were in the ground. Previously, the first machine (S-317) was expected to reach its target shaft on Changxing Island towards the end of this year. However, the shield holed through on 21 May some 20 months after commencing its drive.

Geology along the alignment of the tunnels, which are spaced 23m between centres, comprises sand, clay and rubble. Starting at an excavation depth of 26m below the river, the machines reached a maximum depth of 65m when boring the 7.17km long tubes.

The second Mixshield (S-318) was launched three months after the first machine and if the lag remains then it may breakthrough at its target shaft on Chanxing Island in or before August.

The tunnels are being built by Shanghai Changjiang Tunnel & Bridge Construction Development co Ltd to link Chanxing Island, in the Yangtze, with the mainland at Pudong. The tunnels are part of a larger transport project to link Pudong with another river island – Chongming.

The tubes will be fitted as double decked, the upper level of each tunnel taking a three lane road while the lower level provides space for service and safety installations, and possibly a future metro line.

Breakthrough at the Yangtze

Client ends Bilfinger work on Seymour-Capilano

Metro Vancouver has announced plans to seek a replacement contractor for the Seymour-Capilano tunnels. It claimed it had no option but to terminate Bilfinger Berger's involvement on the project over the contractor's suspension of part of the works since January, despite efforts to agree a new construction plan and method to reduce the safety risk caused by geological conditions.

Bilfinger Berger claimed that the geology along the alignment was significantly different from the assumed conditions that were presented in the bid documents. The contractor claimed that the construction planning and method were, therefore, not suited to the ground conditions expereinced at the site.

Confirming that its contract has been terminated, Bilfinger Berger claimed the move by the client to be unjustified and added that their dispute was now the subject of litigation.

The contractor added further that it has taken appropriate measures to cover the project risks from Seymour-Capilano and that the setback was not expected to impact its financial results.

Bilfinger Berger was building twin 7.2km long raw water and treated water transfer tunnels in Vancouver, Canada. About 2.5km of the former tunnel had been bored, and approximately 2.2km of the latter, when the TBMs were stopped over safety concerns.

Those concerns focused on a zone where there had been incidents of falling rock in the broken, unstable ground, with some injuries as a result. As a consequence, the provincial safety authority called for the TBM drives - with a pair of 3.8m diameter Robbins machines - to be halted.

The drives were being undertaken on a 2.3% downhill gradient and the geology, cited as work started, comprised granodiorite and metavolcanic strata, which were predicted to be competent. However, it was noted that overburden was up to 640m, and there was consequent unpredictability (*T&TNA*, December 2006, p23-26).

While work continued away from the TBM zones, such as to advance the final support and lining, the parties were trying to agree an alternative solution to the construction challenge. Discussions continued following disagreement over the first plan, until the contract was cancelled in late May.

Limberg II breakthrough

The Wirth gripper TBM driving the 3.9km inclined headrace for the Limberg II hydro project, in Austria, has holed through on schedule.

The 7.03m diameter open TBM was refurbished and overhauled for the contract, which required it to bore through basalt and gneiss at a 45° (degree) incline. The rock was of average UCS 100MPa but was locally higher, reaching 150MPa.

Much of the length of the tunnel was unlined, having a minimum excavated diameter of 7m, but shotcrete was used in parts.

An excavation period of nine to 10 months was planned for the drive, which began in August last year following some delays due to weather conditions at the high altitude site. The TBM holed through in April.

Prior to the project the TBM was used on the Ermenek hydro project, in Turkey, and the North Side Storage sewer scheme in Sydney, Australia – where it has a smaller, 6.7m diameter for both projects.

Hamburg U4 gets set

Tunnelling work on line U4 of Germany's Hamburg metro is getting underway with a 6.57m diameter Herrenknecht Mixshield TBM adapted to the soft ground conditions to drive parts of the twin bore tubes.

The Herrenknecht machine (S-440) will excavate 2,810m long stretches of the 4km tunnels being built for the U4 line between HafenCity and the downtown area.

Geology along the route comprises a mixture of gravel, clay, sand and silt. The TBM will drive at depths of up to 42m below the city and parts of the port area and place a segmental lining during advance.

The machine has a cutterhead torque of 3,950kNm, and is equipped with an isolated invert to minimise the risk of clogging. In addition, the stone crusher has the capability to break up rocks that range anything up to 500mm in size.

Factory acceptance of the TBM was in early March.

Breakthroughs at Krolsky, Seville

Lovat has been busy with its TBMs achieving breakthrough on the Krolsky rail tunnel in Russia, and the Seville metro, whilst securing another order in China for the Chengdu metro.

The 9.5m diameter mixed face TBM completed the 2,250m long rail bore at Krolsky, in east Siberia, which had varied and difficult geology with fissures, fractures and high inflow rates.

Geology along the route comprises slate and granite of up to UCS 250MPa, and blocky sections, as well as saturated loose strata. Inflow varied up to 300m^3 per hour.

The TBM (RME375SE Series 21400) will next, as previously planned, be refurbished and upgraded to drive the nearby Mansky tunnel. The 2,500m long drive by the same contractor – Bamtonnelstroy - will parallel an existing rail tunnel. Robbins is also supplying a 4.3m diameter TBM to smaller tunnel for the scheme (*T&TI*, May 2007, p8).

In Spain, the joint venture of Dragados, Sacyr and Cavosa has completed its last drive for Line 1 of the Seville metro with a 6.05m diameter mixed face EPBM. The JV built two sections of tunnel with a combined length of 4,668m.

Groundwater was up to 15m above the invert as the machine (RME238SE Series 21300) bored mainly through gravel with some sand and blue marls. Best advance rates for the EPBM were 29.4m in a day, 175m in a week and 448m in a month.

In China, the company has signed a contract to supply its third 6.3m EPBM to China Railway Tunnel Group (CRTG) for the Chengdu metro, in Sichuan province. The machine (RME246SE) will be used on Lot 11 of the metro's Line 2 works.

The contract progress comes through the local steel structures manufacturing partnership between Lovat and CRTG. The EPBM is to be delivered to site in early 2009, and site support will be provided by Lovat China.

The machine will bore geology along the Line 2 route comprising sedimentary deposits, including gravel and cobbles. To minimise abrasive wear, the TBM cutting face and rim will be fitted with chromium carbide plating. The alignment is below groundwater level. Maximum EPB pressure is expected to be 2bar with groundwater varying 6m-13m above invert level.

Chicago sewer bids

Chicago is planning the construction of a 4,535m long deep combined sewer tunnel plus a numbers of drop shafts for the first stage of the 39th Street conduit rehabilitation project.

The sewer is to be 4.6m i.d., and the drop shafts will range in diameter from 2.2m-4.6m at depths ranging from approximately 70m to 77m. In addition, the tunnel will connect into the existing deep sewer system, known as the Tunnel and Reservoir Plan (TARP), and the contractor will build a variety of other hydraulic structures.

According to the call for bids from the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC), the estimated cost of the project is US$93.2M.

A pre-bid conference was held late last month. The deadline for submission of bids for the contract (01-103-2S) is 17 June, which is also the date the sealed bids will be opened.

The required bid deposit is 10% of the client's estimated project cost, or US$932,000. The client has also set a minimum of 40% of labour and materials costs in the tender offer to be directly borne by the main contractor.

Rock science supports project superiority

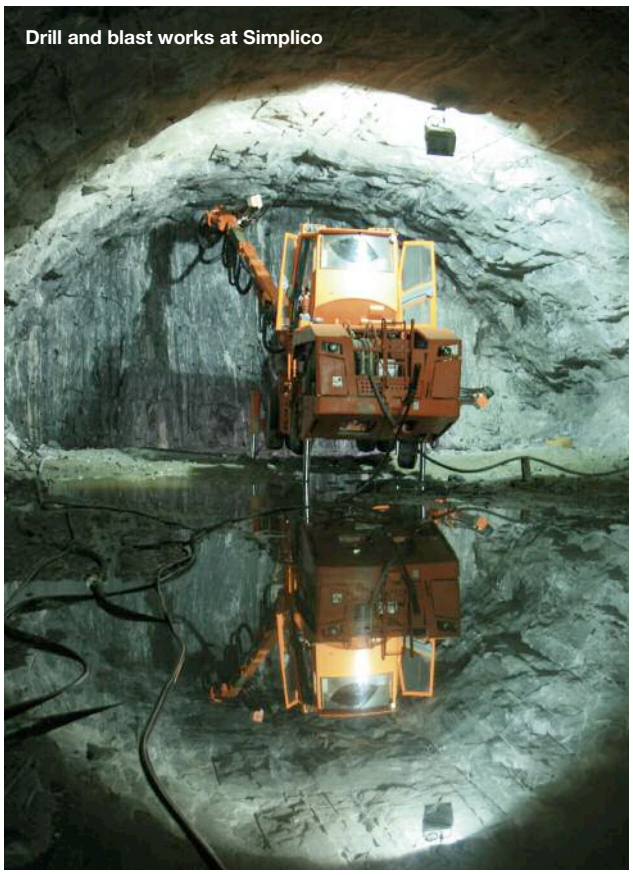



Application expertise gets your business rolling

Tunneling is a challenging art. It requires deep knowledge and years of experience to make it a profitable business. At Sandvik, we have worked for decades with various tunneling methods, in thousands of projects and built a lot of knowledge along the way. As the result, we have developed high quality products, extensive project expertise and comprehensive services for your benefit. Always targeting at boosting your productivity and profitability.

SANDVIK

Simplico stretched by Sandvik


Drill and blast works at Simplico

Drill and blast excavation is underway on six faces of the longest tunnel on the sprawling water conveyance system that will feed the Simplico hydro project in Brazil.

The top bench of the 6,030km long bore is being opened to 7.5m high by 15m wide, the standard width of all four tunnels on the scheme. The lower bench height of the "T3" tunnel will be 7.2m to give a final height of 15.7m.

Geology along all four tunnel alignments comprises gneiss with typical UCS of 200MPa. In recent months, as the excavation gets underway from the upstream and downstream portals and access tunnels a third of the way from each end, to give two faces each, the average advance has been 6m per day.

Contractor on the 36-month project is a joint venture of Odebrecht and Andrade Gutierrez. They have both ordered and are leasing a total of five Sandvik Axera jumbos – two T11 (now known as Sandvik DT11) and three T8 (Sandvik DT8), all of which have three booms. In addition, the rigs have the firm's tools, including the 4.3m long R38-Hex32-R32 rods, 51mm diameter R32 bits and R38 shanks.

A T8 jumbo was used to open up the 7m by 8m access tunnels, and four of the five rigs on the project are being used to drive the tunnel.

The faces are on average advancing by 2.85m with each blast round. Typically, a total of 135 holes are drilled on the face, to 3m lengths, within about 2.5 hours. The drill pattern is 16 holes for the opening (including three cut holes reamed from 51mm to 102mm diameter), 14 foot holes, 39 contour holes and the remainder spaced at radii of 5.05m, 6.25m and 8m.

The excavation sequence has about three rounds per day, including up to 1.5 hours for charging, 40minutes for blasting and ventilation, and up to two hours for scaling and mucking out. The spoil from each round is approximately 264m^3.

The JV contractor is achieving 300m with the drill bits, and achieving 6-7 regrinds with each. The average life of Sandvik tools on the project has been 5,000 drilled metres for the shank adaptor and 2,500m for the H32 rod.

The project is being built along the border of Minas Gerais and Rio de Janeiro states, and is to be completed in 2010.

Gotthard drives push ahead

Almost three quarters of the tunnel excavation and nearly two-thirds of the invert lining on the 57km long twin bore Gotthard Base Tunnel had been completed by the beginning of last month, which also saw the trackwork and equipment contract having been finally signed.

By the beginning of May, a total of almost 110km of tunnels, galleries and passages had been excavated on the project out of 153km. The total length of drives during April was 1,090m. So far, of the total 113km of concreting works required, 61% of the invert has been lined and 38% of the vault.

Excavation is picking up early pace in the Erstfeld section with a recently relaunched 9.58m diameter Herrenknecht TBM (S-421) on its 7.7km drive. It is undergoing test runs and optimisations in the east tunnel. Its sister machine (S-422) is being prepared for launch.

The main focus of activity in the adjacent, 11.35km long Amsteg section is transferring the lining equipment from the east to the west tunnel. The TBMs on the Erstfeld section had excavated these tunnels. The contractor for both Erstfeld and Amsteg is AGN JV, comprising Murer-Strabag, and Strabag.

The only other stretch of significant TBM excavation that remains is in the Faido stretch, which is more than 14km long. The second of the two shields is passing slowly through Lucomagno gneiss while the other has passed ahead with improved advance rates.

The 9.43m diameter Herrenknecht Gripper TBM (S-210) leading at Faido had advanced 1,760m in the east tunnel by the start of May. Having passed through the Lucomagno gneiss zone, progress rates improved up to 14m per day. The machine was launched in July last year (*T&TI*, September 2007, p7).

The sister machine, which was launched in October 2007, has advanced only 810m in the west bore. As the TBM (S-211) is still passing through the gneiss zone, the average advance being achieved is approximately 6m per day.

Furthest advanced on the Gotthard Base Tunnel is the Bodio section, at the southern end of the project. Concrete lining works in the section, which is nearly 16km long, are scheduled to be completed this month.

Bodio's twin bores were excavated by the TBMs now driving the tunnels in the Faido section. The contractor for the Bodio and Faido sections is TAT JV, comprising Implenia, CSC, Impregilo, Hochtief and Alpine Mayreder.

The project will be the world's longest tunnel on its opening and is a key link Europe's expanding rail network. The US$1.5bn contract for the railway fit-out has been formally signed between AlpTransit Gotthard and Transtec Gotthard Consortium, following last year's disputed award and delay risks.


Celebrations at Amsteg

Jinping II first TBM bore set to go

First TBM excavation at the Jinping II hydro project, in China, is due to start this month with a 7.2m diameter rebuilt Robbins machine getting underway to drive a dewatering tunnel ahead of the four headrace bores.

The TBM was previously used on part of the headrace excavation at the Karahnjukar hydro project, in Iceland. The dewatering tunnel is needed on the project due to high inflows expected in the headrace bores, possibly up to 4,000l/s.

Robbins is supplying two machines to the project, and the other is a new 12.4m diameter TBM that is almost 50% assembled in its launch cavern. The shield will drive one of parallel, 16.7km long headrace tunnels ("Tunnel-01").

Onsite assembly of the new TBM is the first time the machine has been built, which is another use of Robbins' system that bypasses full factory pre-erection and dismantling. The company said the system provides earlier machine launch and cut down on shipping risk and cost.

Robbins expects the new shield to achieve average advance rates of at least 800m per month on the 16.7km long bore, as required under the contract. The shield is due to start driving in the latter half of this year. Spoil removal will be by conveyor, and the TBM's own two feeder conveyors have been designed to cope with wet conditions.

The project developer – Ertan Hydropower Development Co Ltd (EHDC) - ordered the two TBMs last year along with a shield of the same size from Herrenknecht. It will have two of the four headrace tunnels ("Tunnel-01" and "Tunnel-03") excavated by TBM and the others by drill and blast (*T&TI*, May, p11).

TBM assembly on site at Jinping II


The back up gantry

Contractors on the tunnelling project are China Railway 18th Bureau (Group) Co Ltd, which is to use Robbins' TBM and also execute a drill and blast drive ("Tunnel-02"), and its sister firm - China Railway 13th Bureau (Group) Co Ltd, which will use the Herrenknecht shield and also do the other drill and blast drive ("Tunnel-04").

Work onsite is advancing despite some delays in cavern excavation and general setbacks for the project in recent months, such as severe snow storms affecting the delivery of large TBM components. The earthquake in Sichuan province last month has also caused road damage near where the large backup structures have been fabricated. Due to limited space onsite most TBM components are being staged approximately 80km away, in Manshuwan.

New face, new run at Hallandsås

After a stop to completely change the entire cutterhead due to abrasive wear and impact damage, the TBM on the first tube of the Hallandsås rail project in a delicate wetland region of Sweden, has been relaunched on the last leg of its drive.

The 10.53m diameter Mixshield (S-246) was launched in October 2005 from the south portal and has progressed 2.5km, or almost halfway, into its drive on first tunnel of the twin tube project.

Geology along the alignment is gneiss, amphibolite and dolorite, a range of extremely abrasive rocks with UCS greater than 250MPa. The rock was also heavily fractured, resulting in significant inflows and block falls, which in turn damaged the cutterhead and disc cutters.

In April, the joint venture contractor of Skanska and Vinci took the opportunity of the TBM holing through into the central access shaft on the project – a carry over from a previous, drill and blast effort at the tunnel scheme – to refurbish the shield and change the cutterhead. The disc cutters have been set deeper in the new cutterhead and were increased in size from 17" to 19". The JV has been working with the TBM manufacturer Herrenknecht and client Banverket on the solutions.

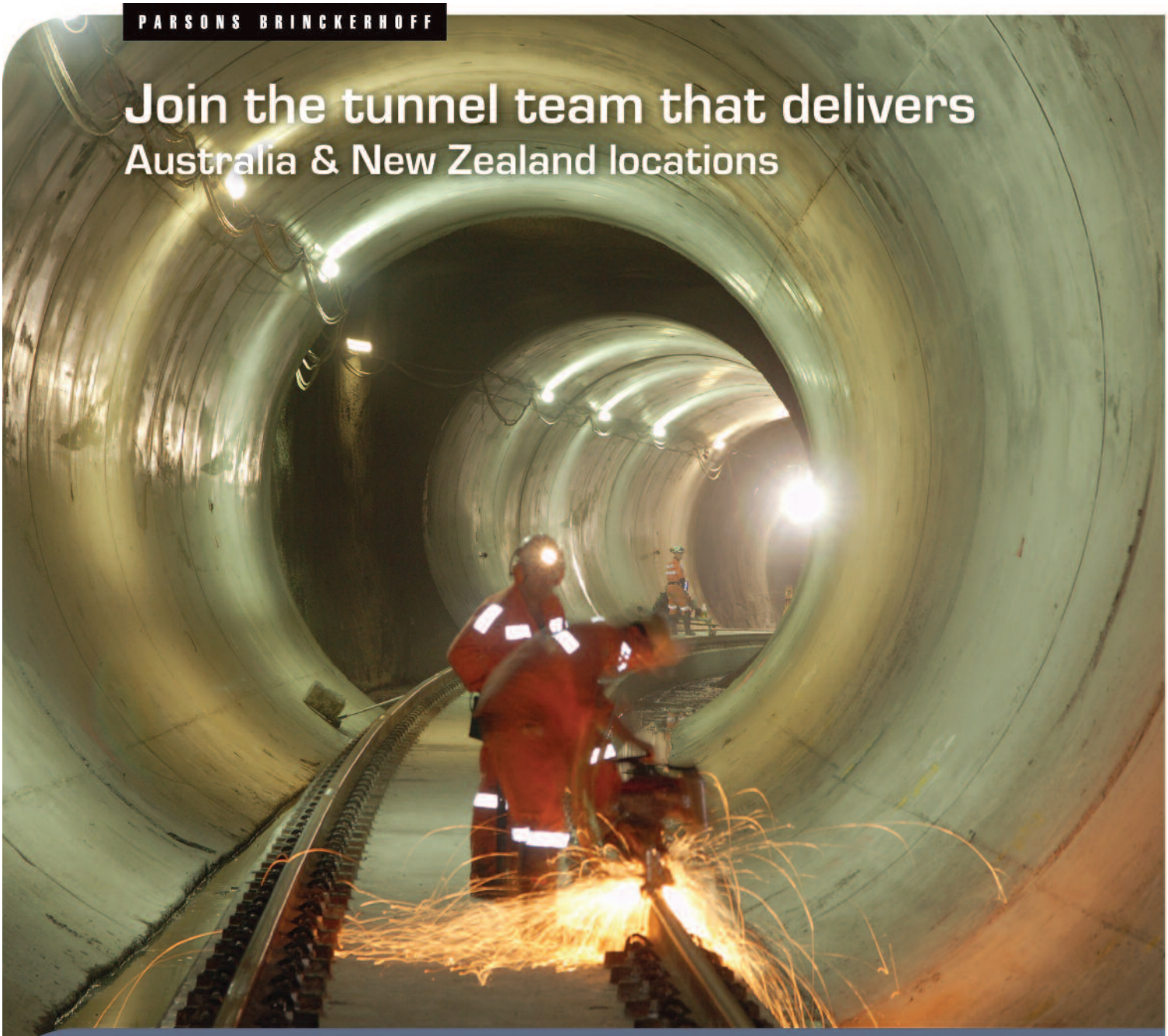
The tunnel excavation can have significant overbreak which results in a minimum annular gap of 220mm outside the 540mm segmental, gasketed lining. Each ring requires approximately 18m^3 of backfill and then secondary grouting is undertaken.

Last month the client announced that groundwater levels in the area had been restored to support the wetlands above the TBM bore. The wetlands had suffered when groundwater levels were significantly drawn down – by 50m-60m – due to the TBM driving through the fractured, blocky strata.

PARSONS BRINCKERHOFF

Join the tunnel team that delivers

Australia & New Zealand locations



Our growing Tunnel Section is Australasia's largest, working for all the major clients on the region's most prestigious underground construction projects. Our clients span every market, including transport, water, power, mining and urban development.

Positions available:

Graduate Engineer
Senior Tunnel Engineer
Senior Mechanical Engineer
Regional Tunnel Team Manager

This is your opportunity to join a team that is ranked at the top. When you join our Tunnel Section you'll have the opportunity to work on all well known tunnelling projects currently happening within Australia. This is an opportunity not to be missed.

For a confidential discussion, please contact Nicole Weiss on +61 2 9272 5622 or nweiss@pb.com.au

www.pb.com.au www.pbworld.com

Adelaide | Bendigo | Brisbane | Canberra | Gold Coast | Melbourne | Newcastle | Perth | Pinjarra | Singleton | Sunshine Coast | Sydney

PB 100 YEARS®

Vinci JV signs 2nd Coen Tunnel

The joint venture led by Vinci and last year named as preferred bidder for the 2nd Coen Tunnel, in Amsterdam, has finally signed the concession contract.

Coentunnel Company BV comprises Vinci Concessions and the group's subsidiaries CFE and Dredging International, as well as outside firms Dura Vermeer, Arcadis, Besix and TBI.

The JV signed the 30-year concession with the Dutch Ministry of Water and Public Works, or Rijkswaterstaat. Its successful bid valued the project at more than €500M (US$775M, up from US$680M when picked as preferred bidder a year ago due to currency effects).

Under the concession, the JV takes over the operation of the existing tunnel for a fee while constructing a new, immersed tube tunnel at its own cost. Once the new, eight lane road tunnel is operational the JV will receive a combined, single payment annually for both tunnels, the level depending on service availability.

The project is to be financed, designed, built, operated and maintained under the concession, which runs to 2037. The construction works are due to last approximately five years.

Last year, during the procurement process, there were delays in selecting the preferred bidder due to a question over contract conditions. Three prequalified JVs submitted tenders (*T&TI*, July 2007, p12).

Moody's downgrades Lane Cove

A year after it opened, poor traffic flow has led Moody's to downgrade the underlying senior secured credit rating of the finance company for the Lane Cove toll tunnel in Sydney, New South Wales.

The credit agency said that the average daily traffic levels in the 3.6km long link during February and March – 62,400 and 59,000, respectively – were well below the base case forecasts made five years ago. It downgraded Lane Cove Tunnel Finance Co's (LCT) the underlying rating from Ba1 to Baa3, but noted that the Aaa wrapped rating was affirmed.

LCT is the finance company for Connector Motorways Group (CMG), which owns Lane Cove Tunnel and the Falcon Street Gateway. The CMG joint venture comprises Thiess Contractors, John Holland and Dutch bank ABN Amro. The transport link was developed at a cost of almost US$900M.

Moody's added that debt service needs, in the face of such lower revenue from the toll tunnel, meant the link did not merit an investment grade rating – even after allowing for an optimistic ramp-up profile for traffic flows.

The rating remains under review for possible further downgrade despite LCT's good liquidity reserves and its forecast rise in traffic as alternative roads are cut back. Moody's said its key concern is over the ability of LCT to service debt but added that the company had sufficient funds to meet all cash calls until late 2009, without further traffic increases.

Lane Cove is not the only toll tunnel in Australia to have suffered revenue difficulties. Following its experience with Cross City, a 2.1km long link elsewhere in the capital, Hong Kong's Cheung Kong Infrastructure decided to also exit Lane Cove around the time of the opening, in March – a month ahead of schedule (*T&TI*, July 2007, p12).

Step up in tunnel courses

Last month the ITA launched a new initiative to help tackle resource shortages in tunnelling by offer its endorsed Masters courses in Asia and elsewhere in Europe.

The new ITA committee driving the initiative is based at Turin University, where courses are already offered alongside training also made available in Madrid and Lausanne.

Former ITA president André Assis is leading the initiative, which is being directed through the newly formed Committee on Education and Training (ITA-CET). The initiative will establish the ITA University Network.

In a statement, the ITA said the move was its response 'to resource shortage and allowing younger engineers to refocus their talents on the opportunities' in the sector.

In separate training developments, at the World Tunnel Congress (WTC) in India, in September, sessions will be offered covering a number of aspects of tunnelling.

The specific courses are: geotechnical and geological investigations under high overburden; design of underground support system for deep tunnels; mechanised tunnelling technologies; control of seepage under high hydrostatic pressure; urban tunnelling and associated problems; ventilation systems in long tunnels, and, fire safety.

In the UK, the BTS will later this month run a five-day course on tunnel design and construction. It will be held at Brunel University, outside London.

London tube needs advanced

London Underground (LU) has requested the PPP Arbiter to provide guidance on costs that metro upgrade concessionaire Tube Lines may incur in future, while its parent Transport for London (TfL) last month took control of the other, failed, concessionaire Metronet.

The tube owner has asked the PPP Arbiter to give guidance on the costs that Tube Lines could incur in the second 7.5 year period of its public-private partnership (PPP) agreement and performance levels. The guidance requested is a formal procedure under the PPP agreement.

Guidance from the PPP Arbiter is expected to be given to LU by early September, as requested. Last month the parties were brought together for initial discussions and in June the process will move to detailed the submission and response stages between LU and Tube Lines. Ongoing discussion will then proceed over the coming months to establish final guidance and technical reports.

Tube Lines is responsible for the infrastructure improvements on the Jubilee, Northern and Piccadilly lines.

The focus on potential costs is acute following Metronet going into administration over extra costs and dispute with the client over reimbursements. Last year Metronet requested the PPP Arbiter to assess its claims but the significant shortfall on the merited reimbursement led it into financial crisis. The business went into administration and only emerged from that process last month when TfL took over the business and its responsibilities.

TfL said that it plans to invest approximately US$2.8bn through Metronet in station upgrades, rolling stock and signalling in the present financial year. Work is continuing on 22 stations following activities on 39 other stations. TfL said that design work is underway on the same number of stations again.

Metronet, via two sister businesses, is responsible for the renewal and upgrades on the Bakerloo, Central, Victoria, waterloo & City, Circle, District, Hammersmith & City and Metropolitan lines.

Tube Line and Metronet were awarded their PPP deals in 2003, and the cost management is being performed in four 7.5 year period.

Dywidag JV wins Algeria metro job

A joint venture led by Dywidag International has been awarded a contract to extend partly underground Line 1 of the metro in the Algerian capital, Algiers.

The contract calls for 4km of new route, more than half of which will be underground. Work has already commenced on site for the project though clearance for the approximately 32-month project is anticipated by September.

Construction of the 2.7km long single bore tunnel for the metro line is to be executed by the New Austrian Tunnelling Method (NATM), said Dywidag's parent group, Strabag. Four box stations are to be built by cut and cover for the project.

Geology along the route comprises three main strata: young glacial sediments with cohesive characteristics; below is molasses with sandy, clayey deposits, and groundwater level at 15m depth; and, the deepest layer is homogeneous, impervious clayey marl.

The NATM drives will proceed from two shafts, which are expected to take about four months to sink. Tunnelling is to commence in February 2009 and it is expected that three, possibly four, faces will be excavated at peak. Cover to the excavations, which have a 63m^2 cross-section, will range from 7m to 26m.

The excavation with primary lining is to be finished by March 2010, then another year is planned for the final lining. The primary and secondary linings will have a combined thickness of 400mm. The tunnel will be sealed by a grout umbrella, membranes and a concrete invert.

The €252M (US$390M) contract involves construction of the underground and surface sections, the four stations, and bridges over a road and a river. The entire project with its tight schedule is one of the largest and most complex in the country, said Strabag.

Dywidag is the majority (51%) partner in the German-Algerian-Italian JV, which includes partners Cosider and Trevi. The firm has an office in Algiers. The local economy is becoming more active, with consequent increased traffic and movement of people, as the country benefits from development of oil and gas reserves.

The capital plans to build three metro lines with a total length of 56km and 54 stations. To date, approximately 8km of route has been constructed with eight stations.

Rights issue boost to Eurotunnel

Eurotunnel raised approximately Euro313M (US$484M) through the rights issue at the end of last month that was oversubscribed.

The rights issue is the final part of its two-step financial restructuring of the formerly struggling Anglo-French transport infrastructure group, which owns the Channel Tunnel and operates shuttle train services between Folkestone and Calais.

Just over 31.3M new shares were privately placed at a value of €10 (US$15.5) per share. The offer was closed the day it opened, not least because of the strong interest of institutional investors. The new shares are to be listed early June.

Jacques Gounon, chief executive, said: 'Following the success of the public placement, the significant over-subscription of the private placement confirms the keen interest of investors in the new Eurotunnel.'

The cash injection follows an earlier issue of subordinate deferred stock, which raised an aggregate amount of approximately €841M (US$1,300M) and was used to partly settle debt. The new stock issue will also contribute to debt reduction. As a consequence of the lower debt, Eurotunnel will face significantly reduced interest charges over the next couple of years.

Financial structuring and improved traffic flow enabled Eurotunnel recently to report its first, pro-forma profit, which was for 2007. The earnings were slightly in the black for the period, at US$2M (*T&TI*, April, p13).

The rights issue was managed by a syndicate of banks comprising ABN Amro, HSBC, Lazard-Natixis, Lehman Brothers and UBS Investment Bank.

Tyne Crossing contracts awarded

Volker Stevin Marine and Halcrow have been awarded contracts on the new river Tyne crossing, in north east England, by the main contractor Bouygues Travaux Publics.

A contract for US$32M has been awarded to Volker Stevin Marine to build the immersed tube tunnel for the river crossing at Newcastle and Gateshead. The business is a joint venture of sister companies within the VolkerWessels Group – Volker Stein and Volker Stein Construction Europe.

The immersed tube tunnel will be the 360m long key element of the new 1,600m long transport link. The tube is to be formed by four precast concrete sections, each 90m long and 8.5m by 15m. The sections are to be built in a nearby drydock on the Tyne and floated into position and submerged in the third quarter of 2009. In total, the tube will require 14,400m^3 of reinforced concrete.

Halcrow has been awarded a contract to design the mechanical and electrical systems for the project. The consultant had supported Bouygues during the procurement phase and provided a risk assessment for the tunnel fire suppression system

Under the concession, the existing Tyne crossing will be refurbished and operated and a new crossing built and run. The concession was awarded in November 2007 and the construction and refurbishment work is to take four years (*T&TI*, December 2007, p7).

The concessionaire comprises Bouygues Travaux Publics (a subsidiary of Bouygues Construction), HSBC Infrastructure Fund Management Ltd and Bank of Scotland Corporate. Financing of the scheme includes equity from the partners as well as a subsidy from the client, the Tyne & Wear Passenger Transport Authority (TWPTA).

Other companies that have supported concessionaire include High-Point Rendel, Parsons Brinckerhoff and Faber Maunsell.

SELI

BORING THROUGH FUTURE

www.selitunnel.com - www.selitecnologie.com

TBM Systems Manufacturers & Tunnel Builders

SELI is today the only global tunnelling Company, with over 600 Km of tunnel projects in all continents and able to cover the full range of market demands:

TBM systems manufacture

Tunnel Builders

TBM systems overhauling and rental

TBM operation services and supervision

Rolling stock

Segment moulds

Victoria Relief

Plans for congestion relief at Victoria station, in London, call for two box excavations plus a series of weaving, mined foot tunnels that call for a major programme of jet grouting of waterbearing strata. Report by Contributing Editor, Patrick Reynolds

The scale of the envisaged sprayed concrete lining (SCL) tunnelling works and associated jet grouting being planned for the congestion relief scheme that is part of the Victoria Station upgrade, in London, are more akin to the scale of excavation projects in the waterbearing strata of Continental Europe.

While it is anticipated that SCL will be employed, as the weaving mined foot tunnels would require too many tapered section for an SGI alternative (although that is not ruled out for bidding contractors), the combination with the jet grouting would also be the most extensive use of the "European" method in the UK to date, according to the client, London Underground (LU), and lead consultant Mott MacDonald.

With few precedents for significant SCL-jet grouting combinations in the UK, they add that an example of such a construction system in Continental Europe is the Cologne metro. At Victoria, most of the tunnel profiles will be excavated in waterbearing River Terrace Deposits, only the invert level being around the London Clay horizon.

Therefore, most of the ground improvement works will involve forming a grouted arch over the alignments of the new foot tunnels, or Paid Area Link (PAL), plus some regular cut-off walls. Yet, given that the system is foreseen as the way to execute those most difficult technical aspects of the congestion relief project, the critical path for the project itself runs through the expansion work needed for the existing, underground South Ticket Hall which provides main access to the tube station from the surface rail station. It is the frontline of the major interchange station.

Congestion: Problem and Solution

Most weekday mornings, LU operations staff are required to close off access to the South Ticket Hall an average of three to five times at rush hour before 9am. As a result, one common sight and sound of London commuter life is hundreds of rail passengers existing Victoria rail station only to be briefly kept out of the tube,

being held up behind the barriers at the "Sussex Stairs" that lead to the ticket hall.

The tube station platforms – Victoria Line and for the District & Circle (D&C) Lines - have reasonably sufficient capacity for the numbers arriving, but a key problem is the throng is coming from the one direction, funnelled in from the main station into the foot tunnels. The existing PAL splits at the South Ticket Hall to feed the D&C platform and the deeper, Victoria Line platform from its southern end.

The congestion relief solution, therefore, is to add additional access to the Victoria tube platform from its northern end. A new, North Ticket Hall is to be built below a major one-way road and neighbouring buildings that LU wants to demolish. The challenge for the project designers has been both to connect the box station to the live tube platform and also tie it back to the main interchange station – via the South Ticket Hall – by constructing an extended PAL network of up to 300m in total length.

Establishing how to size and build the box stations, and weave the new PAL tunnels through the well populated underground infrastructure environment, has been a communications as well as a technical challenge.

Discussions, and negotiations, with the many stakeholders in the area of prime real estate resulted in the main axis of the PAL tunnel being shifted; the new foot tunnel axis had originally to run parallel to the tube platform but that concept was changed as the route also would take it below Victoria Palace Theatre. As a consequence, the spine of the PAL tunnels will cross over the tube's Victoria platform tunnels, resulting in the extended foot tunnel system now to run in a "Z-shape" between the ticket halls.

The PAL tunnels were also kept at a high level above the Victoria Line station, and London Clay, for a host of reasons, including: the need to provide links to the D&C Lines; to avoid longer passenger transfer times; and, there was the reality that extensive ground treatment would still be required for those tunnels within the Terrace Deposits.

Stakeholder talks with a developer and others, in relation to the South Ticket Hall extension, led to the initial plan to be trimmed back to ensure the key, one-way Wilton Road directly outside the mainline rail station was kept open.

Road to tube upgrade

Looking back to the 1990s, the congestion problem at Victoria was evident. Today, during the morning three-hour peak approximately 70,000 passengers use Victoria tube station, and a rise of 20% is expected by 2016. Annually, approximately 80M passengers use the station, and the demand forecast is to be 25% higher by 2016. The congestion relief scheme is to increase the station capacity to meet the rising demand.

Consultants were appointed by LU to examine the possibilities for congestion relief at the tube station and then, in 2003, its parent – TfL – developed proposals for the whole transport interchange at Victoria station. Further consultancy studies, by Arup principally, examined potential solutions but the congestion relief scheme remained priority for LU.

By mid-2004, it was recognised that there was an affordable congestion relief scheme that could be undertaken. It was included in the TfL Investment Programme for 2005-2010 and had a budget of US$996M (in 2005 currencies). The Victoria Station upgrade, focused on the congestion relief, therefore really got started in April 2005, as a LU project with a dedicated internal led by project director Peter Lynch.

He has spent much of his career with LU on major projects such as early work on Crossrail and the Canada Water station and tunnels to Canary Wharf on the Jubilee Line Extension (JLE). Having also worked for some years with consultants, including Scott Wilson's rail unit which he set up and led in 2003, he rejoined LU that year to work on VSU.

A scheme design to RIBA Stage D was developed by October 2006, and shortly afterwards a competitive process was initiated to appoint consultants for the detailed design work – civil and structural engineering, tunnelling, M&E, environmental assessment, support for the consent process, architecture, passenger movement modelling, construction planning, cost and programme.

Mott MacDonald was appointed lead consultant and is led by project manager of the MDC2 team, Mark Leggett. Having worked in the UK and North America, his previous work in the capital includes London Bridge station on JLE, the Heathrow Terminal 5 tunnels, and hybrid Bill design for Crossrail.

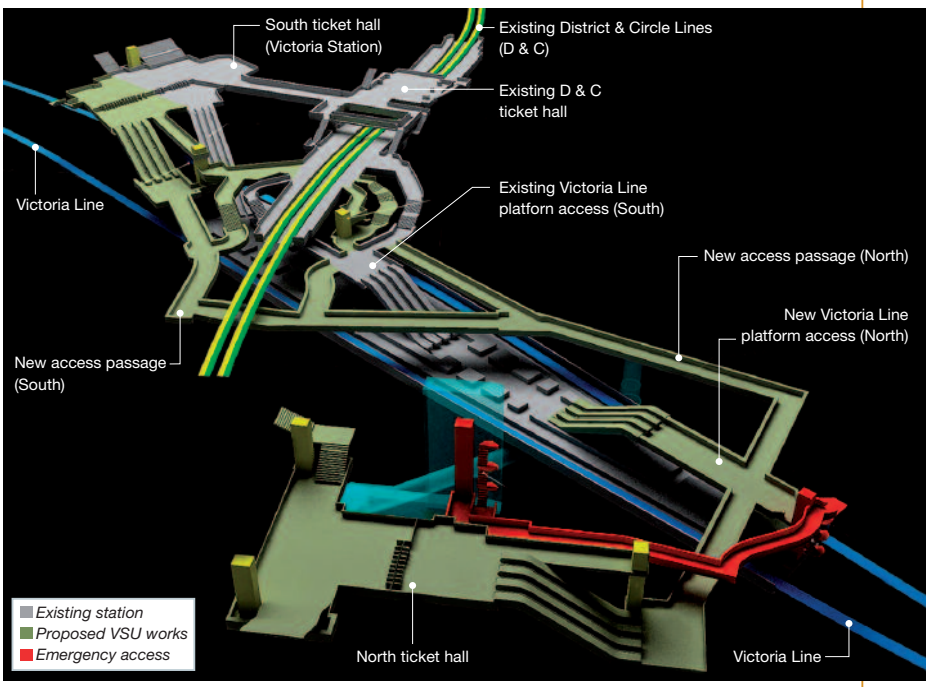
Motts' multi-disciplinary team includes London Bridge Associates for construction planning, Weston Williamson Architects, MVA, F&A/Corderoys, Gall Zeidler, Rupert Taylor and Alan Baxter Associates.

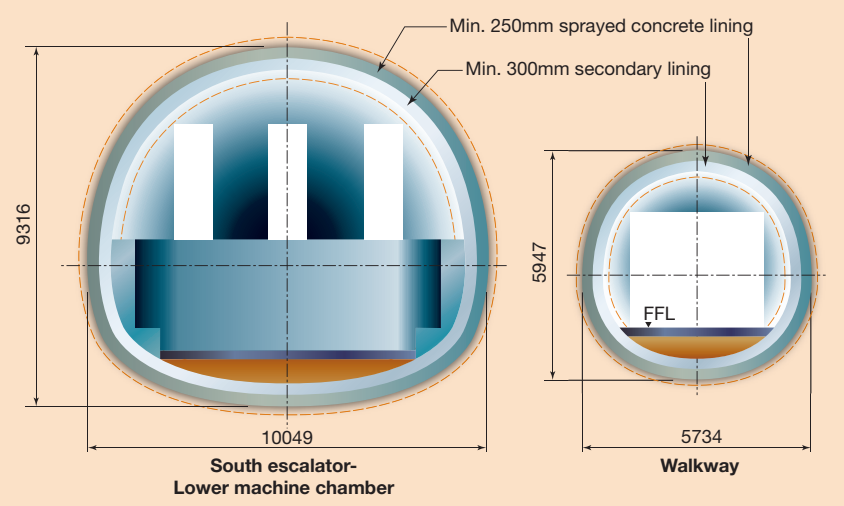
With subsequent analysis on the developing design the cost, discounted to the second quarter of 2007 for planning documents and submissions, the resulting budget was basically the same at just over US$978M (at Q2-'07 currencies). In November last year, LU made an application for a Transport and Works Act Order, which has an inquiry scheduled to commence late October this year.

Procurement and Preparatory Works

In January the client issued an OJEU notice for construction works that indicated a

Below: The congestion relief project at London's Victoria Tube Station requires the construction of box stations linked by SCL tunnels





Above: **Cross sections of the PAL Tunnels vary in size, and their construction will require significant jet grouting of River Terrace Deposits**

price range of US$685M-US783$M, and deadline for expressions of interest to prequalify was the end of that month. By the end of May a shortlist had not been drawn up and LU declined to name those firms interested for reasons of commercial confidentiality.

LU plans to put the construction work out to tender as a single contract in Q3. It plans to use the NEC form of contract, which will be target cost with undisclosed incentives and penalties.

Drawing upon the company's experience of redeveloping King's Cross station with box construction in congested roads and tunnelling works, plus having a single contract, means LU will have a small management team. This is quite different to the multi-section and multi-contract Crossrail project which will see the employment of delivery partners. In addition, LU has set up a single, co-located project management office at Victoria where consultants are already housed and space has been reserved for the contractor.

The client anticipates that, subject to the public inquiry, it may be able to decide on the contract award in 2009. It hopes that the congestion relief project will be completed as soon as possible after the separate Victoria Line upgrade works, due to be finished in 2013.

Preparatory works are already underway for the main scheme. There are two projects that are described as both 'urgent and critical' – utility diversion and asbestos removal.

Birse is management contractor for the utility diversion, for which detailed design is being finalised. The diversion works should be substantially complete before construction of the main scheme commences. On the asbestos removal works, which started mid-2007, the material is being taken from any part of the tube system that may be affected by the scheme, such as ticket halls, ceilings, back rooms, platforms and escalators. The works should be finished by Q4.

Box Stations & PAL Tunnels

The congestion relief works will increase the number of tube ticket halls at Victoria from two to three – the enlarged South Ticket Hall and the new North Ticket Hall for the Victoria Line, and the existing D&C hall which will be untouched.

Box stations will be built in stages at both locations using secant pile construction, for which internal columns will be installed as plunge columns to connect intermediate floor slabs as the top-down excavations proceed. The works will be undertaken while the tube and rail systems at Victoria remain operational.

To be built below "The Beach" triangular plaza outside the main rail station, the South Ticket Hall will be 30m by 40m by approximately 8m deep. A new, second, 30m long escalator barrel – the largest excavated chamber (9.3m high by 10m wide) on the project – will connect to the "Z-shaped" PAL tunnels. Following the changes at the Wilton Road boundary, the internal layout, including M&E facilities, was re-configured.

The box station for the North Ticket Hall will be approximately 75m by 30m by 10m deep and built in two stages. Following the grant of the necessary powers for the scheme, and before first stage excavation below Bressenden Place road, LU will demolish key adjacent buildings (3-11 Bressenden Place & 120-124 Victoria St).

The area will be used for construction site facilities, to establish a temporary traffic diversion route, part of the new ticket hall and also provide access for the PAL tunnel excavations. With the diversion in place, the main road will be opened up. After that stage has been completed, the road will be reinstated and the remainder of the box station then excavated in the demolished site area.

Working from the access point in the demolished site area, the tunnel works will be advanced through the "Z-shaped" PAL layout towards the new escalator barrel of the South Ticket Hall. At their south end, the PAL tunnels will also have three short links to existing passenger tunnels (two to the D&C lines, one to the present platform access route to the Victoria Line).

At the north end, the PAL tunnels will lead to a 30m long escalator barrel down to the north end of the Victoria Line platform, and also join the North Ticket Hall. In addition, an emergency access tunnel will be excavated between the box station and a shaft sunk between the Victoria Line running tunnels, just beyond the north end of the existing platform and, therefore, behind the escalator barrel.

Geology and ground treatment

The main strata of concern for the tunnel works, and the cut and cover boxes, is the River Terrace Deposits that underlie the alluvium (peat, silt, clay) across the entire site. The strata varies in thickness from 4.8m-6.6m and overlays London Clay, the top of which will also be penetrated by the tunnel excavations.

There are two distinct gradings, either a well-graded sand and gravel with less than 5% fines, or a poorly graded fine and medium sand, occasionally with greater than 5% fines. It is expected that the grading will vary both vertically and horizontally over a relatively short distance.

Within the vicinity of the VSU project, the strata is typically medium dense, occasionally dense and very dense, although some boreholes encountered loose deposits during site investigation at the north and south ends of the project area. The materials were variously described as: silty and slightly clayey, slightly gravely sand; gravely fine to coarse sand; and, sandy to very sandy gravel.

In terms of groundwater, the level is 6m-8m below the surface. Level data indicate there is no significant flow to the River Thames and that there are only limited influences from rainfall recharge. The data are also consistent with the simple model of flow in the area, which is controlled by the D&C drainage system.

In terms of ground treatment, although

ground freezing is feasible the potential use is limited by the presence of major sewers and potable water supplies. Borehole pumps will not be used on a large scale on VSU; dewatering from the surface is only anticipated to be used to verify that the jet grouted arch zone over the PAL tunnel routes is effective in excluding water.

Tunnel construction

With the many tight turns and junctions in the layout of the new PAL tunnels, the more economic and practical method of excavation is expected to be SCL.

Using SGI as an alternative lining would call for fabrication of many bespoke tapered segments, and would not eliminate the need for ground treatment. Additionally, other difficulties in seeking to use SGI would be fabrication lead-time, availability within the UK and, not least, the inflexibility to layout change should obstructions be encountered. However, traditional construction could be employed in some areas for square work for smaller sections, and steel frames for new openings in platform tunnels.

The ground treatment will generally see localised dewatering used throughout the tunnel alignment as the faces advance, aided by the additional ground treatment of transverse jet grouted barriers, at intervals.

The excavation sequence is anticipated to work with: verification of groundwater and the effectiveness of the grout seals from the surface; forward probing at the face and drainage of any residual water; possible supplementary ground treatment; installation of a grouted pipe arch in the crown; possible installation of spiles; the benched excavation will see the top heading advancing using SCL followed up by the closure of the invert approximately 2m behind the face.

The excavated dimensions of the majority of the PAL tunnels are approximately 6m high by 5.5m wide. A few smaller cross sections are 4m by 3.9m while the escalator barrel for the North Ticket Hall has sections of 6.8m by 7.7m and 8.2m by 7.7m. The escalator barrel at the South Ticket hall will be a bigger excavated chamber however, as noted previously.

The benched excavation will be lined with a combination of shotcrete, mesh and lattice arches, and, most likely, a waterproof membrane. The primary lining will be 250mm thick in smaller section, 300mm in the most common and larger cross-sections. The secondary lining will be 300mm for all tunnels.

Constructability of the tunnels is being examined by the design team in conjunction with London Bridge Associates and Gall Zeidler Consultants, and ground improvement and building protection advice is also provided.

While recent and historical projects in London have been used to inform decision-making, the nature of the works – anticipated SCL construction with significant jet grouting – as noted earlier has led to consideration of the tunnelling techniques used on Continental Europe, and farther afield.

As London looks ahead to rise in the volume of tunnelling work with Crossrail and Thames Tideway plus utility projects over the next few years, with much of the focus of TBM activity, the VSU congestion relief project presents a different, landmark opportunity for the UK to utilise the “European” approach to soft wet ground tunnelling. T&T

Eliminating mine water pollution using HDD

When a collapsed adit in a closed coal mine, in Wales, caused serious pollution issues, HDD technology came to the rescue. Technical journalist, Ian Clarke, explains the novel solution adopted

For some 30 years now Horizontal Directional Drilling (HDD) technology has been earning a reputation as a solution to various, largely utility based, underground pipeline/casing installation projects. There have been numerous road, rail and waterway crossings, sea outfalls and the like installed using HDD, which has been used to limit disruption to transport services, minimise environmental impact and allow the hustle and bustle of every day life to continue largely uninterrupted.

Most of these works have been for the construction of water and gas pipelines and cable installations as well as, more recently, on-line and grade sewer construction. However, just now and then, the technology comes to the aid of some quite unusual situations, many of which appear to be environment related in one way or another. Scotland-based HDD specialist Longbore was involved in one such, ultimately award winning, project.

As part of Wales' Glyncastle Minewater Remediation Scheme, designed to address pollution problems associated with the old, and long closed, Glyncastle coal mine, Atkins Limited, acting as consultant engineers for the Coal Authority, invited Longbore to submit a design for a directionally drilled bore to enable the interception and capture of contaminated mine water in the Neath Valley in South Wales.

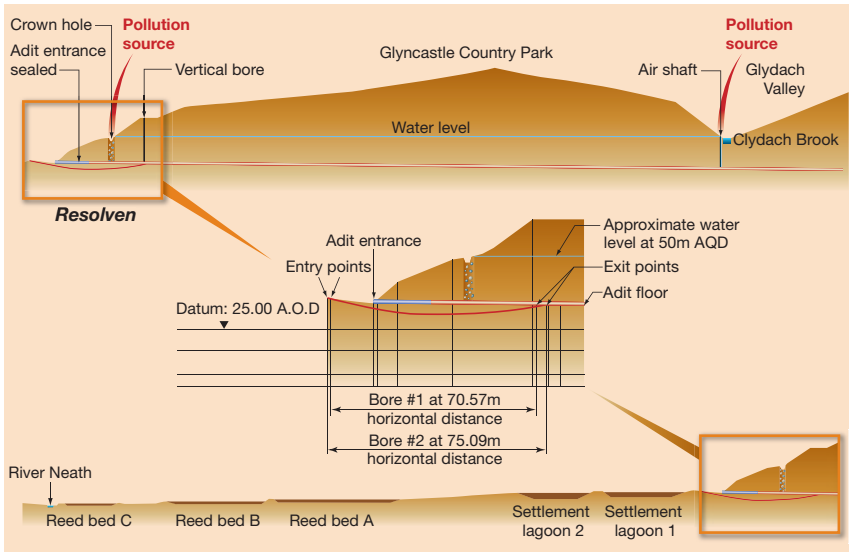
The former Glyncastle colliery had been mined since 1875. When it was abandoned in 1965, the mouth of the Tyn-y-Cwm adit was sealed up and, following a collapse in the adit in 1994, water levels within the mine rose causing an accumulating of dissolved iron of up to 60mg/l within the mine water. The contaminated mine water began to escape from the ground at a number of diffuse locations around the old adit, most notably from the collapsed crown hole above the adit in Resolven, a village located some 14 miles north of Port Talbot, South Wales. Emanations also occurred at an airshaft in the adjacent Clydach Valley, causing staining of the Clydach Brook and the River Neath with orange ochre. This situation also prevented salmon from spawning in these water courses.

Atkins proposed that, if the contaminated mine water could be captured, it would be possible to treat it via a series of settlement lagoons and reed beds before the flows were re-released back into the River Neath.

Drilled solution

The diffuse nature of the mine water discharges can be likened to an overflowing bath. After careful consideration of the problem, the solution proposed by Longbore was to utilise horizontal directional drilling

Below: **The mine water outflows colour the local water courses rust brown due to the high iron content, at the Air Shaft in the Clydach Valley**
Right: **The mine water pollution at the Crown Hole in Resolven**



Left: Fig 1 – A section through the Resolven bore site showing the path of the main bore in relation to the mine workings

techniques to drill into the lowest point of the mine workings from below, effectively 'pulling the plug out of the bath' and allowing the mine water to exit the mine workings in a controllable manner. Doing this from a location below the level of the adit would allow the mine water to flow out under its own head of pressure. Conventional vertical wells drilled into the adit from above would require abstraction pumps and associated power supplies, which would bring with it ongoing maintenance and therefore cost implications.

To complicate matters, although the water levels had to be lowered to below the existing discharge points, if they dropped too far and air was allowed into the mine shafts, oxidation of the dissolved iron would take place within the mine and ferrous deposits would begin to accrete in the discharge pipelines and valves that were to be installed to capture and control the flows. Additionally, this situation could promote the presence of mine gases within the adit. A system to control the mine water flow would therefore have to be installed. However in order to accomplish this, two significant issues had to be overcome.

The first major problem would be drilling into a mine tunnel system containing a water level some 17m above the proposed drilling rig elevation. A head of pressure of over 170kPA had been estimated given the information available on mine water levels. If this water pressure was not contained during the drilling process, the entire mine would discharge with catastrophic results for the project and the local environment. Longbore's solution was to cement a surface casing into the bedrock at the bore launch site, onto which was bolted a series of gate valves and rubber snubbing units designed to allow the various drilling and hole opening assemblies to be run in and out of the well while maintaining circulation and pressure control over the drilling fluids and the mine water once the pilot bore holed out.

Bore guidance was also critical to success of the project. Although the location of the adit beyond the collapse had been confirmed with a vertical bore, the width of the adit was unknown, so the target point for the drill had to be as close to the vertical bore as possible. As directional drilling is a three dimensional process, the bore also had to punch into the adit floor at the correct azimuth and inclination to allow sufficient pipe to be pushed into the adit to clear the anticipated sludge levels on the floor of the mine tunnel.

As the target point for the bore was 30m below ground level, a real time wireline magnetic guidance system was specified for the project in preference to a surface based locating system. No records were available relating to the abandonment of the mine and if steel rail tracks or pit props had been left in the mine, they would interfere with the quality of the magnetic survey. A downhole magnetic target was therefore mobilised to use as a back up guidance option, although in the event it was not required.

Completing the bore

Having had the design approved, Longbore was sub-contracted to complete the required drilling work by Interserve Project Services Limited, the Coal Authority's

Right: An overview of the drilling site set up for the first of the two bores undertaken at the former Glyncastle colliery

framework contractor, on a fixed price lump sum contract.

Longbore decided to utilise its American Augers DD-6 HDD rig, and its associated equipment to complete the bore. A comprehensive Health, Safety & Environmental plan was established prior to work commencing although no operating accidents, near misses or environmental incidents were incurred during the course of the project.

The vertical Site Investigation bore was pumped to provide a water supply for the drilling operation, and to attempt to reduce the mine water to a manageable level.

Drilling commenced using a 170mm diameter steel, Milled Tooth tri-cone drill bit fitted to a downhole drilling motor. This assembly was attached to an adjustable bent housing set to achieve the required curve build rates and directional control.

Ground conditions at the site comprised Silesian Sandstones, locally known as 'Ironstones'. The drilling operation achieved an average Rate of Progression, (ROP), of some 13m/hr to the initial casing setting depth of 43m. Tungsten Carbide Insert drilling assemblies were available on site in case the prevailing rock conditions proved to be harder than anticipated, although in the event they were not required. The pilot hole was then opened in two passes to first 305mm diameter and then to 510mm diameter.

During this stage of the drilling operation, prior to the installation of the pressure control device, dense drilling fluids were utilised to provide hydraulic control over the mine water in the event that contact between the mine and the bore was experienced. As a contingency, barite weighting agents were available on site to increase the density of the drilling fluid further if required.

The 355mm diameter SDR-17 surface casing pipe was electro-fused together, with a cement basket being mounted on the leading joint, which was then run into the borehole. A tremie pipe was then run into the annulus between the pipe and the bore and the surface casing was cemented into place and allowed to cure, so providing a pressure tight seal.

The pressure control device and diverter system was then attached to the wellhead and the 170mm diameter drilling assembly was used to drill out a cement shoe.

Drilling then re-commenced toward the adit floor and progressed to the target at an ROP of 6.4m/hr. Great care had to be taken to ensure accurate surveying. Ultimately the drill head entered the adit at a drilled distance of 71.7m, at an accuracy of 0.1m to the left of target and 0.5m long of the target. The pilot hole assembly was removed from the bore under pressure, and the hole opening assembly was used to open the pilot bore to 305mm diameter.

The 200mm diameter SDR-11 Butt Fusion Welded drainage duct was prefabricated in a single length and Longbore utilised its patented Pipe Pushing Technology to insert the duct into the enlarged bore, again controlling mine water egress using the snubbing unit. An inflatable packer was used to isolate the annulus between the drainage duct and the surface casing. Cement was then pumped into the void to provide a physical seal.

On completion of the first bore, the pipeline was valved and gauged and placed in operation to drain the mine water whilst the drilling rig was moved and a second back-up pipe installation was installed using the same methodology.

Success

The completed scheme has successfully enabled the contaminated mine waters to be captured, so eliminating emanations from the diffuse discharge points that had led to the original pollution problems. The new controlled discharge pipeline has enabled controlled flow to be transferred to a sustainable treatment system that is currently reducing the mine water iron content to <1 mg/l. In addition, the newly constructed wetlands have provided a biodiverse habitat for flora and fauna as well as a new local leisure amenity.

Above: **Drilling into the Adit. Note the wellhead for pressure control of the mine water during the drilling operation**

According to John Ritchie, managing director of Longbore: "To our knowledge, this is the first time well head pressure control equipment been used in conjunction with a Horizontal Directional Drilling project in the United Kingdom. It use has provided a potential solution to diffuse groundwater control and contaminated land remediation for the numerous abandoned mines in all parts of the country."

In recognition of the innovation and success of the Glyncastle Minewater Remediation Scheme, Longbore were awarded a United Kingdom Society of Trenchless Technology (UKSTT) New Installation - Small Project Award and an International Clean Up Innovation Award. T&T

Right: **The drilling site for the second bore for the back-up pipeline**

Beauty is in the eye of the beholder

Born to be completely and uniformly worn out, the new Sandvik *RT300* drifter bits dramatically cut downtime in mining and construction operations. The more aggressive, fractured or fissured the rock, the more significantly longer the service life of the *RT300*s.

The tailored metallurgical properties of the new Sandvik cemented carbide *XT48*, the precision manufacture and the R&D programs used for their development – plus the numerous field tests to perfect them – have resulted in unprecedented performance quality. So, if button failure is a problem, Sandvik *RT300* drifter bits are the solution.

Even if button breakage is not a problem, you can still expect a 10 to 20 percent increase in bit service life.

Beauty? For the professional there is more to it than first meets the eye.

SANDVIK

SANDVIK MINING AND CONSTRUCTION TOOLS AB SE-811 81 SANDVIKEN SWEDEN TEL +46 26 26 20 00 www.miningandconstruction.sandvik.com

Tunnelling a lifeline to the ocean

Australia's Gold Coast Desalination Project's tunnelling programme remains on target. Carla Carroll, senior communication consultant for the GCD Alliance, describes the project so far

Above: **An aerial view of Australia's Gold Coast desalination plant**

So critical is the timing, the countdown continues to the completion of the Gold Coast Desalination plant, a vital piece of infrastructure that will provide 125 megalitres of fresh drinking water per day to the South East Queensland region on Australia's east coast.

South East Queensland is Australia's fastest growing region, attracting 55,000 new residents annually. Regional growth projections, the extended drought and supply considerations have highlighted the need for new initiatives to guarantee water supplies in the longer term.

This region is currently experiencing the worst drought in recorded history and water storage levels are at record lows. This, combined with unprecedented population growth, has necessitated the implementation of a number of new water initiatives.

Queensland has joined a growing number of countries throughout the world that have opted for water desalination as a proven solution to meet future community water needs.

The US$1.15bn Gold Coast Desalination project is currently under construction and located on a six hectare site at Tugun on Queensland's Gold Coast, adjacent to the western side of the Gold Coast Airport. Construction of the plant commenced in November 2006. The plant is due to begin producing water at the end of November 2008, with operation at full capacity by January 2009.

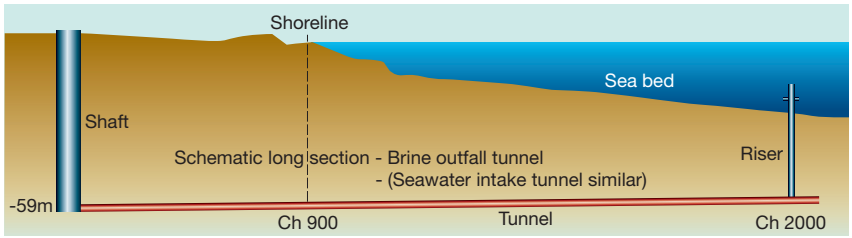
The desalination plant will form a vital part of the Queensland Government's new US$8.6bn SEQ Water Grid and the Gold Coast City Council's Waterfutures Strategy.

This water grid will link all water sources across SEQ together. This will enable water to be easily transferred from population to population across the region. The desalination plant at Tugun will be integrated with the other sources of water through the development of the water grid. Investigations into desalination as an emergency water source are consistent with the implementation of this strategy.

Desalination was chosen as the community's most favoured fresh water option after extensive community consultation in 2005. This survey asked the community to select an option that did not rely on rainfall or other surface water storage methods.

Tunnelling

Tunnel construction is on target as two 150-tonne TBMs powered their way through bedrock 50m beneath the sea to complete the Gold Coast Desalination Project's two ever so crucial marine tunnels, which will link the largest desalination plant on Australia's Eastern Seaboard to the ocean.



Above: **Fig 1 – Longitudinal section of the tunnels and risers**

Following the arrival of the two US$9.6M purpose built slurry TBMs, manufactured in Germany by Herrenknecht, they have been working 24 hours a day, seven days a week to construct the 3.04m o.d. 2.2km long intake and 2km long outlet tunnel, which were both completed in February 2008 in preparation for the November 2008 deadline. The intake tunnel will collect the seawater and the outlet tunnel will disperse the brine.

International interest

The nature of the project and the strict time frame for its construction attracted the employment of leaders in this field nationally and globally.

The Gold Coast Desalination Project is being constructed for SureSmartWater (a 50/50 joint initiative between Queensland State Government and Gold Coast City Council) by the GCD Alliance, comprising John Holland Constructions, Veolia Water Australia, Sinclair Knight Merz and Cardno. The Alliance will also operate the project for 10 years.

At the helm of the project's tunnelling and marine operations is Tony Bermingham, who is working for John Holland Group. Bermingham has worked on a number of iconic tunnels throughout the world, including the Channel Tunnel linking the UK to France, Athens Metro, and the CTRL Thames Tunnels to name a few.

Bermingham, who is assisted by tunnelling manager, Matt Lennon, and marine manager, John Holmes, for John Holland Group, identified that the tunnel design and construction provided numerous challenges, which his expert team has met eagerly. These challenges included:

- Designing and constructing the tunnels and having the necessary equipment delivered within the tight time frames
- Assembling an efficient tunnelling crew from scratch
- Working 40m below the seabed
- Working under 3.5 bar of compressed air, when water ingress into the TIM cutter-head was 4000l/minute, required numerous interventions
- Training the tunnelling work force to work in compressed air conditions and how to operate the air-lock

Bermingham said that the slurry tunnelling method was chosen over other mixed-ground methods, such as EPBM, due to the sub-aqueous conditions and in response to the soft ground conditions and settlement control. "We chose two purpose-built slurry TBMs because they have minimal impact on both the environment and the community. They are also safer and more robust, particularly when going under the seabed with limited geotechnical information available," said Bermingham.

The slurry TIM and supporting equipment was adaptable to handling the geological conditions using slurry pipelines in the tunnel. A significant solids separation treatment plant (STP) was installed at the portal to support the tunnel excavation sequence.

"We also needed to ensure the tunnel lining was durable enough to cope with the constant flow of saltwater, 70m underground (40m below the sea bed) for a minimum design life of 100 years," said Bermingham.

"Our tunnel design and construction is the result of considerable research to ensure the best possible product for the South-East Queensland community – tunnels that that will be able to help provide drinking water for the region well into the future," Bermingham said.

The TBMs consist of three shield sections, which were lowered down the two 70m deep access shafts by a 300 tonne crane and then assembled in the tunnel launch chambers. The remaining six backup gantries were lowered to form the complete 71m long TBMs.

Each TIM cutterhead has 24 disk cutters. The excavated rock is crushed and mixed with bentonite to form a slurry, which is then pumped to the STP where the clay is separated from the crushed rock. This is only the second time slurry tunnelling has been used in Australia. The first was the Herrenknecht system used on the Sydney Airport Tunnel project back in 1998 (*T&TI*, October 2000).

The TBMs have excavated some 52,000m^3 (approximately 125,000 tonnes) of high quality metamorphic siltstone (argillite), which is being used as engineering fill at the neighbouring Gold Coast Airport area. The siltstone is very fractured and relatively soft (up to 120MPa), and there is the potential for direct connections through the 70m overburden of the tunnels to the maximum 76m depth of the sea above. This provided potential for a maximum 7.5 bar water pressure on the tunnelling system. There was also the risk of sudden, large volume inflows into the excavation chamber.

Having started in June 2007, excavation of the tunnels was completed by February 2008. During the eight months of constant

Right: **A view of the sections of TIM on the surface waiting to be lowered down the 70m shafts**

Above: **A view inside the lined outlet tunnel, 70m underground**

24h/seven days/week, tunnel excavation averaged an impressive 75m per week.

A lining first for Australia

As the TBMs advanced, a pre-cast lining ring, consisting of six steel fibre reinforced concrete (SFRC) trapezoidal segments, were placed using a vacuum erector and held in place with 12 shove rams. This is the first time trapezoidal SFRC segments have been used in Australia. The system was selected to negotiate tight radius curves on the alignments and to meet high long-term durability criteria.

The tunnel lining specifications included:

- A compressive strength of 50MPa
- A first crack flexural strength of 4.6MPa
- Quality benchmarked to a Quality System AS/NZS ISO 9001:2000

To ensure durability and strength, and to minimise porosity, the concrete mix included silica fume and fly ash. In addition, a high-range water reducer was used to provide a low water/cement ratio of .35. Finally, to increase corrosion resistance, ductility and durability, 35kg/m^3 of steel fibre was added to the mix.

Each segment is connected to the preceding ring using plastic dowels with steel bolts on the radial joints. These steel bolts will be removed to avoid corrosion and spalling of the concrete. The longitudinal joints of the nominal 1200mm long trapezoidal rings are offset 10° to the axis of the tunnel and the circumferential joints taper from 1193mm to 1207mm allowing the tunnel to navigate through the minimum 400m radius curves.

Forty-eight segment moulds were designed and fabricated by Precast Concrete Products (in Wacol, Brisbane). A programme of 96 segments/day was required by the casting yard to meet the 75m/day programmed advance rate of each TIM. Trapezoidal vertical joints were incorporated in the design to ensure the structural integrity of each tunnel and to allow rapid installation. On average each ring build took approximately 11 minutes.

The journey of each TIM followed a precise route. A survey grid was coordinated by GPS, and this information programmed into the VMT guidance systems on each TIM. The machines were then guided by a laser beam to each target (e.g. from the plant site to the marine riser locations). Once commissioned, each TIM excavated approximately 75m/week of the 3.4m o.d. (2.8m i.d.) tunnels.

Intervention

During construction of the two tunnels, planned cutterhead interventions were required at least every second day. On occasions, these TIM interventions required the need to work in compressed air conditions, due to the rapid inflow of groundwater (approximately 4000 l/min) into the face of the TIM.

Increasing the air pressure at the front of the TIM via compressed air pumped through a pipeline, the inflow of water into the work area was reduced allowing workers to enter into the cutterhead to carry out maintenance works. This meant that team members would spend up to two hours in a hyperbaric chamber after each shift intervention to safely decompress to normal atmospheric conditions.

About 10 specialised tunnellers, including TIM operators and tunnel constructors, were required to work in each TIM. Approximately 100 tunnellers were required to work on both the intake and outlet tunnels (above and below the ground) in two 12-hour shifts. Some of the other tunnelling roles include:

- Project and shift engineers
- Tunnelling superintendent & shift bosses
- Air lock operators (compressed air conditions)
- Safety coordinator

Access to the tunnel is via an Alimak lift in the 70m deep shafts. Five, six-tonne diesel Plymouth locomotives are used in each tunnel to transport equipment, materials and crews from the base of the shaft to the TBMs. Ventilation was an installed 600mm diameter ventilation duct installed in the crown of the tunnel. The fans were multi-stage axial flow.

Once the work of the TBMs was complete, their trailing gantries were recovered. The shield sections and cutterheads were left behind, buried deep under the seabed, as there was limited time available to allow for their complete removal.

Marine

Off-shore, a self-elevating platform (SEP) barge is being used to construct the two marine risers, positioned approximately 1.5km off the coast of Tugun. The marine risers, when in place, will connect via a cross-cut, to the intake and outlet tunnels at about 40m beneath the seafloor.

Construction of the cross-cut involved using traditional hand mining methods through exposed ground. Steel sets and timber lagging were used to construct the 2m diameter x 4m long cross-cuts.

The SEP barge carried a 600 tonne crane and 120 tonne piling hammer to create these marine risers by driving to refusal a 3m diameter caisson. Once the required depth was reached a 1.5m diameter fibreglass reinforced marine riser pipe was lowered into the caisson alongside the tunnel. The space between the two was then filled with high strength concrete to form a reinforced concrete riser pipe.

During plant operation, the intake tunnel will be gravity fed through the low velocity riser at approximately 0.5m/sec, less than ambient sea currents, so the capture of sea organisms in the intake tunnel is low.

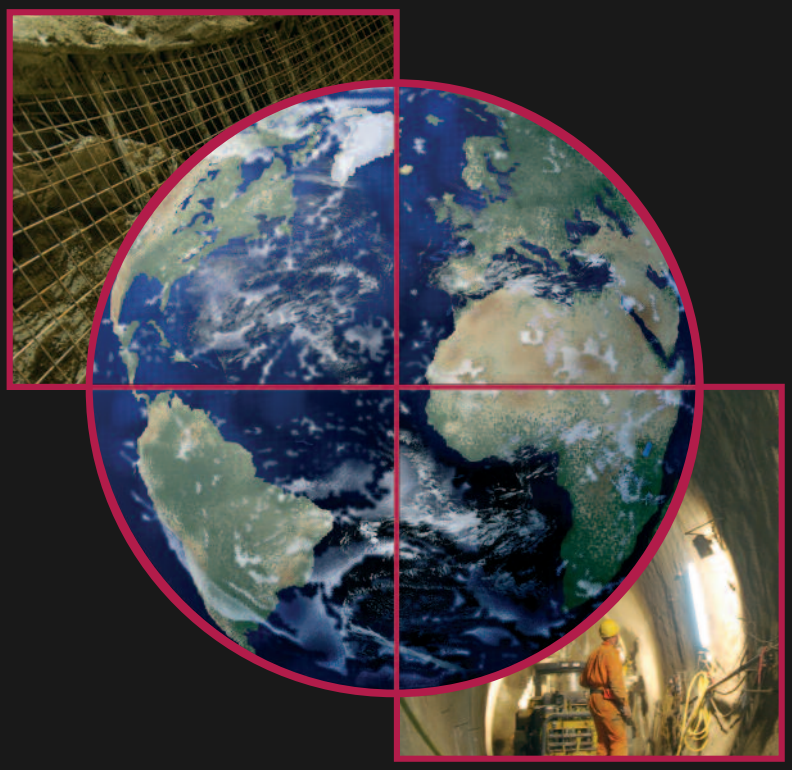
The marine riser for the outlet tunnel is fitted with a high-efficiency diffuser dispersing the brine in a relatively small mixing zone of about 120m by 225m. At the edge of this mixing zone, the salinity of the water is modelled to be almost at background salinity levels.

Operating at 100% capacity, approximately 334 megalitres of seawater each day will be fed into the plant to produce 125 megalitres of fresh drinking water. This plant is one of only two in the world to separate backwash material before returning salt water to the ocean.

All tunnelling and marine programme works are on track and are scheduled for completion by mid-2008.

When complete, the Gold Coast Desalination Project will provide 125 megalitres of fresh drinking water per day to South East Queensland, which is approximately 20% of South East Queensland's water needs. T&T

GROUND CONTROL SOLUTIONS



Each tunnel has a different geology and requires specific customized products and systems. DSI Tunneling Products and Systems match these requirements perfectly.

Our extensive R&D activities guarantee innovative, flexible and reliable underground support products to control every imaginable condition. We offer a complete line of high-quality ISO 9001:2000 certified and patented products. DSI is a leading company in the development, production and application of ground control solutions for the tunneling market. In line with our strong service approach, we are always committed to satisfying our customers' demands.

Rock Reinforcement

DYWIDAG THREADBAR® Anchors

Rebar Rock Bolts and Spiles

IBO, IBI & DYWI® Drill Self-Drilling Bolts and Spiles

Expandable Friction Bolts

AT – Power Set Self-Drilling Bolts and Spiles

Mortar-Mixing Pumps

Rock Support

Steel Arches and TH-Beams

Liner Plates

Pantex Lattice Girders

AT – LSC-Elements Lining Stress Controllers

AT – Casing System

AT – Pipe Umbrella Support System

AT – Drainage System

AT – GRP Injection System

DYWIDAG-SYSTEMS INTERNATIONAL

DSI

Local Presence – Global Competence

TUNNELING SYSTEMS

www.dsi-tunneling.com

Headquarter Tunneling
ALWAG Tunnelausbau Gesellschaft m.b.H.
Pasching/Linz, Austria
Phone +43-7229-6 10 49 0
Fax +43-7229-6 10 49 80
E-Mail office@alwag.com

Pasching
AUSTRIA

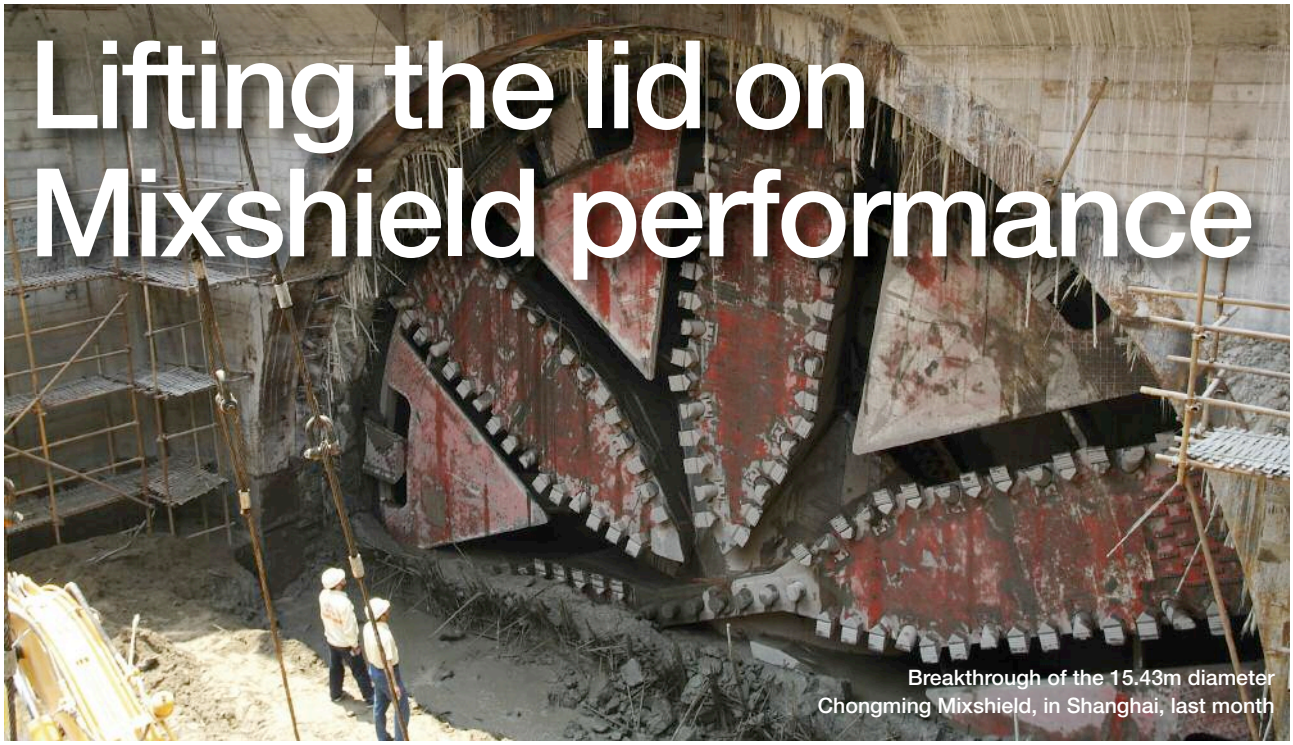
AMERICAN COMMERCIAL INCORPORATED
Bristol, VA
USA

COMMERCIAL STRUCTURES & SYSTEMS LIMITED
Nottingham
UNITED KINGDOM

DSI SOPROFINT
Santiago de Chile
CHILE

DYWIDAG-SYSTEMS INTERNATIONAL DSI
Bennetts Green, NSW
AUSTRALIA

Lifting the lid on Mixshield performance



Breakthrough of the 15.43m diameter Chongming Mixshield, in Shanghai, last month

There remains much potential for the future development of Mixshields, particularly in terms of increased diameters and higher face support pressures. In part two of their article, Werner Burger and Gerhard Wehrmeyer, of Herrenknecht AG, look at two particularly influential projects and their impact on future Mixshield technology

A glance at the development of Mixshields over the past two decades (figure 8) shows an impressive increase in tunnel diameters. What's more, from a TBM technology and manufacturing point of view, there is no obvious technical limit on further increases.

Diameter increases are closely connected to the planned purpose of a tunnel. Two and three lane road tunnels have now been constructed with diameters of 11.2m (A86 Road Tunnel, Paris) and 14.2m (Lefortovo Tunnel, Moscow), and a three-lane road tunnel is currently being built in China with a diameter of more than 15m (Chongming, Shanghai).

With these diameter increases, multi-purpose or combined-use tunnels such as road/water storage (SMART, Kuala Lumpur) or road/subway (Silberwald, Moscow) are also becoming more widespread. The ability to excavate very large diameters also creates additional potential for new usage concepts, like subway station platform tunnels.

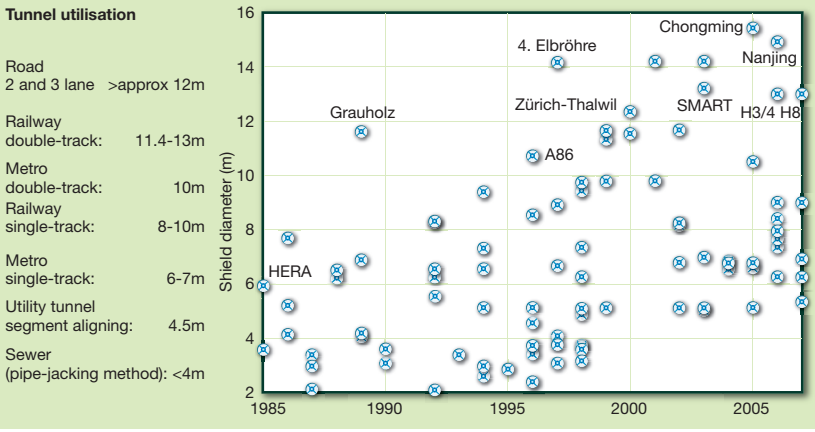
Twin-track rail tunnels with diameters of 11.4m-12.6m already exist, and the increasing speed of trains and higher demands of operational safety (emergency rescue/escape concepts) will create further need for larger tunnel and machine diameters.

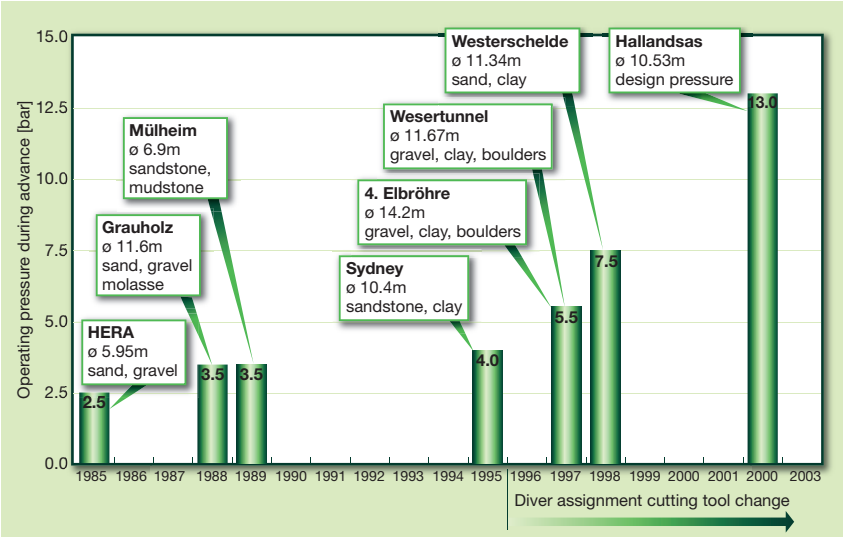
Increasing performance demands, combined with experience from past projects, has also contributed to a continued increase in Mixshield operating pressures (see figure 9). Compared with EPB machines, the Mixshield's use of a closed slurry circuit as the mucking system enables higher face pressures to be effectively dealt with. Controlling a large pressure drop in a continuous mucking system is also easier with a slurry circuit than with a screw conveyor, especially in heterogeneous or highly permeable ground conditions.

A significant increase in face pressure affects all components of the shield that are exposed to the surrounding soil or groundwater. In particular, it affects:

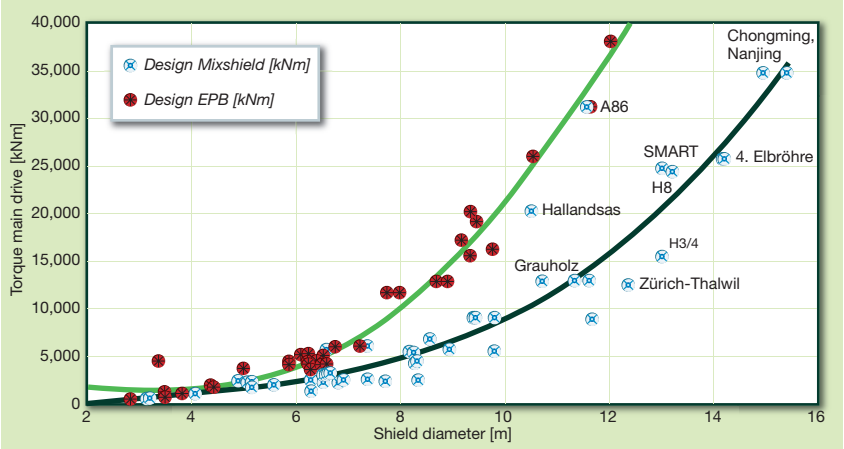
- Shield structure
- Tail seal systems
- Main bearing seal systems
- Articulation seals
- Shield thrust system
- Slurry circuit
- Equipment (and procedures) for face access

Below: **Fig 8 - Diameter development of Herrenknecht Mixshields**





Above: **Fig 9 - Operating pressure of Herrenknecht Mixshields**



Above: **Fig 10 - Torque comparison of cutterhead drives (Mixshield vs EPB-shield)**

While it is possible to accomplish the required shield thrust by changing the number or diameter of the thrust cylinders, far more sophisticated technical solutions are required for seal systems. This is especially true of the main bearing seal system, which is one of the most sensitive design elements in high-pressure applications. For support pressures beyond 4 bar, pre-stressed cascade systems are used with the individual cascade chamber pressures automatically following the face pressure.

These systems can handle pressures far beyond 10 bar for an extended period of time in dynamic mode without the risk of overloading the individual lip seals. Long-term field experience with large diameter drive systems (bearing diameter range of 6m) with face pressures of 7 bar to 10 bar already exist and full scale workshop and commissioning test programmes with pressures of 15 bar have been performed successfully. In emergencies or extended stoppages (long-term static mode), additional inflatable seals are included.

While it is now possible to address high-pressure operations by using appropriately designed equipment, the key questions now relate more to the potential, and the limitations, for chamber access under hyperbaric conditions.

Technical solutions to reduce the need for man access to the excavation chamber are available and currently include:

- Accessible cutterheads for atmospheric cutter tool change (larger machines only)
- Remotely activated standby cutter tools
- Load detection and wear sensor systems

However, these technical features will not totally eliminate the need for a “Plan B” for manual intervention to cover unforeseen conditions or worst-case scenarios.

Based on the system of excavation and face support, a Mixshield requires lower cutterhead torque compared with an EPB shield (figure 10), as the cutterhead is only excavating the ground at the tunnel face into the suspension-filled excavation chamber. The excavated soil sinks towards the submerged wall opening in the invert due to gravity, assisted by the flow direction of the circulated slurry, and is carried to the suction pipe after clearing the rock crusher and suction grille.

An EPB shield requires a comparatively high torque at the cutterhead because, in addition to the soil excavation, the cutterhead itself acts as a mixing tool inside the excavation chamber, which is completely filled with muck.

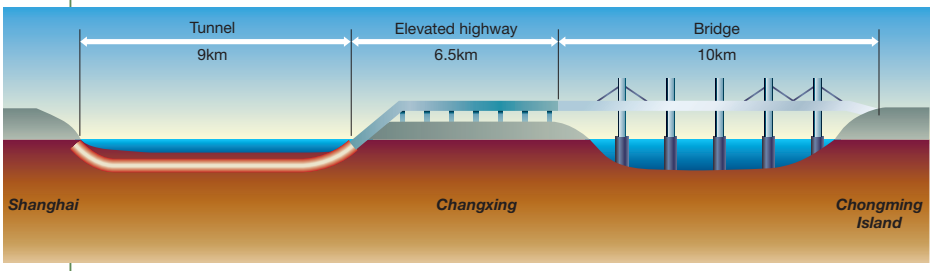
Therefore by adopting high torque EPB drive systems that have been developed for large diameter machines, such as that used on the M30 project, in Madrid (with 125,000kNm), there is huge potential for the development of larger diameter Mixshield machines.

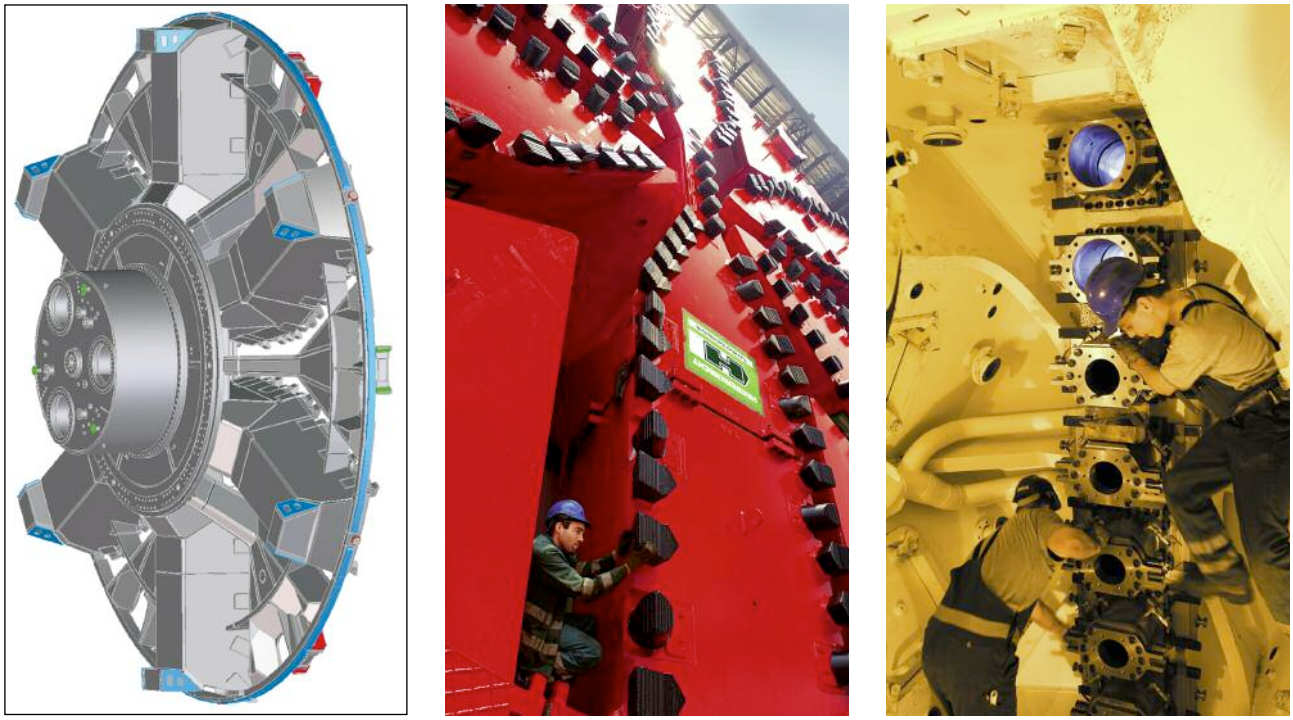
Examples of projects

The following presentation of the Chongming and A86 tunnel projects demonstrates the efficiency of current Mixshields and the value of development.

Mixshield used as a shield with slurry supported face – Chongming, China: A twin tube road tunnel is currently being built beneath the Yangtze River in the city of Shanghai, comprising two 7160m-long bores with three lanes each. The tunnel, along with a new bridge, will link the islands of Changxing and Chongming to the freeway system and city. The geology of the tunnel is defined by its position in the river delta, consisting of soft clay deposits and thin sand layers. The tunnel has an outside diameter of 15m. The pre-cast concrete ring consists of 9+1 segments with a length of 2m. The segments are 640mm thick and weigh up to 16.7 tons. The basic concept of the two Mixshield machines for the project is based on experiences from the Mixshield used at

Below: **Fig 11 - Chongming alignment**





Above: **Fig 12 - Accessible cutterhead: Design (left); front view (middle), view from inside (right)**

the fourth Elbe Tunnel and advancements in large diameter shield developments in high water pressure conditions. With a shield diameter of 15.43m, the two machines are currently the world's largest diameter shields.

The Mixshield machines have following technical features:

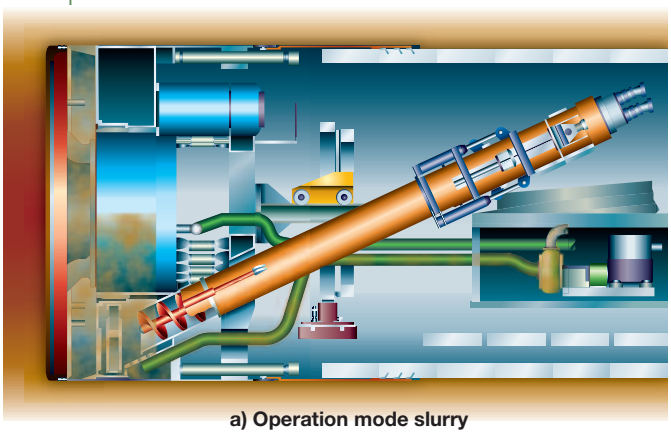
- The shields are designed for an anticipated operational pressure of 6 bar at springline level. Due to the underwater application, and nearly straight alignment, (Rmin = 4.000m), a shield articulation joint was not included
- The invert area of the Mixshield is equipped with two agitator wheels (Ø1.900mm), which assist the material flow to the grille and a 500mm diameter suction pipe. Submerged wall gate, bentonite nozzles, cutting wheel and extensive excavation chamber flushing arrangements complete the Mixshield configuration to address the soft soil conditions and potential clogging risks
- The double shell tailskin with integrated grout lines has a three-row wire brush seal and an inflatable emergency seal system. Furthermore, freezing lines are integrated into the tail shield, which, in case of emergency, can be used for ground freezing around the machine to minimise the risk of water inrush during brush seal changes or repair works
- The cutterhead is designed with six main spokes accessible under atmospheric pressure. To reduce the need for pressurised face access, one complete set of cutting tools (covering the entire face area) is exchangeable under atmospheric conditions from within the cutterhead spokes. To suit to the anticipated geology, the cutterhead was equipped with massive scrapers. Two hydraulically operated overcutters can create an overcut of 40mm in radius. The cutterhead front and outer areas, as well as the rear, are designed to be durable and wear resistant to cope with the single drives of more than 7000m (see p31).

As an additional safety feature, the Mixshields are equipped with all components – such as air locks and installations – necessary for pressurised face access including saturation diving activities.

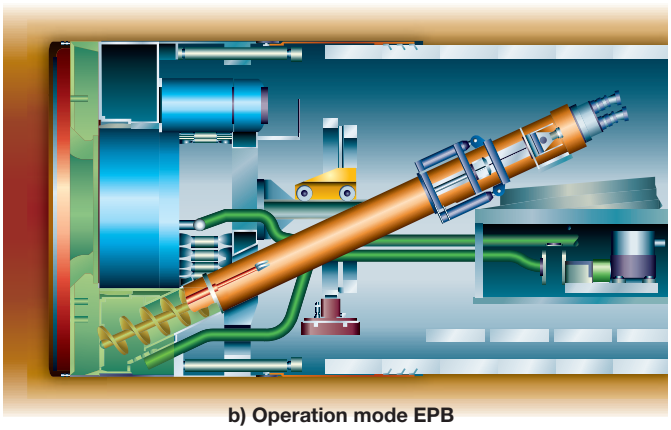
The installed cutterhead drive power is 3750kW and the bearing diameter is 7.6m. The torque of the variable frequency electrical drive is 34800kNm, the shield thrust capacity is 203000kN and the TBM system is designed for a nominal mining speed of 45mm/min.

The three-section backup system has an overall length of 118m and is divided into primary backup, bridge section and

Below: **Westerschelde's Mixshield incorporated an accessible cutterhead for tool changes**



a) Operation mode slurry



b) Operation mode EPB

Above: **Fig 13 - Machine concept of the A86 Mixshield, used in Paris, France**

secondary backup.

The primary backup, or first three-deck trailer, contains all the hydraulic power packs and electrical systems for the supply and operation of the shield, along with slurry pumps and backfill grout system. For an even distribution of the wheel loads the trailer contains an integrated support system of auxiliary rail elements (steel invert slabs) and multi-wheel sets. The prefabricated 35 ton invert elements are installed in the area under the 67m bridge section. The supply crane system is installed inside the bridge cross-section to transfer segments, grout and other consumables to the TBM. All installations and workplaces for extension of services are located in the third section, along with ancillary equipment.

The machine is supplied with segments and grout by rubber-tired transport vehicles, which travel in convoy and carry either segments only or segments and grout tanks. The segment transfer on the backup is done by segment crane and a segment feeder. The grout is supplied in transfer tanks to the first backup.

The shield structures and assemblies of the 132m-long and 2,300 ton TBMs were manufactured in Shanghai. Cutterheads and other main components such as drive assemblies and thrust cylinders were manufactured in Germany and shipped to China. After shop acceptance, the TBM was disassembled and transported to the start shaft about 6km from the workshop.

Tunnelling started for the first tube in September 2006, and in January 2007 for the second. In March 2008, the first 7160m tunnel was about 90% complete and the second about 70%. Constant weekly performances of 90-120m are now being achieved by each TBM. Both drives are scheduled to finish in 2008 (the first TBM in May, and second in September), almost a year ahead of the project schedule.

Mixshield used in differing operational modes – A86 tunnel: To close the gap in the A86 orbital motorway, a 10.1km-long, two-deck road tunnel for cars has been built to the West of Paris. A second tunnel for trucks is planned for construction at a later stage. Two levels, with three lanes each, require an outer diameter of 11.565m. The tunnel crosses the entire spectrum of geological formations under Paris: Marl, clay, limestone, chalk and sand as well as three different groundwater levels. For optimum adaptation to the geological conditions, the machine had to operate in different modes:

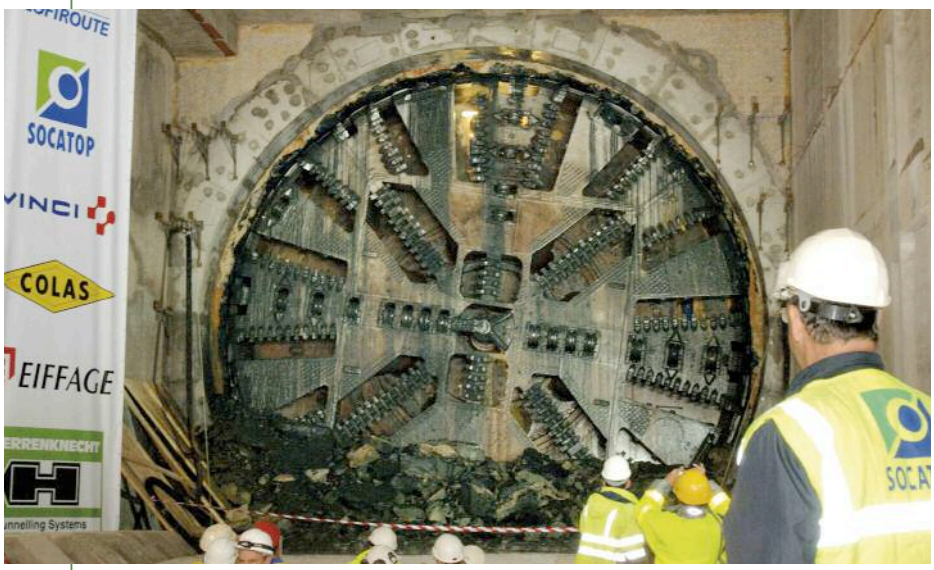
- As slurry shield with slurry supported face (slurry operation - see figure 13a)
- As earth pressure balance (EPB) shield with face support provided by conditioned muck (see figure 13b)
- In Semi-EPB, or compressed air, mode
- In open mode (muck discharge via screw conveyor, non pressurised excavation chamber)

The change between different operational modes is carried out within the tunnel and, depending upon the level of preparations, can take between 1.5 to 3 days. Shield and backup are equipped with the full range of equipment for each mode. For slurry mode, this included a full slurry circuit with submerged wall/pressure wall installation and also a rock crusher. For EPB mode, components such as screw conveyor and TBM conveyor were installed.

The cutterhead is designed for use in all modes of operation without the need for modification. The cutterhead concept is a closed wheel type with a full set of mixed tool equipment including 17" backloading disc cutters and ripper tools for two directions of rotation.

In slurry mode, the excavation chamber and the lower part of the pressure chamber are filled with bentonite slurry; the upper part of the pressure chamber contains the air bubble, and the entire area is pressurised. In EPB mode only, the excavation chamber is pressurised so the submerged wall becomes a pressure bulkhead. The pressure chamber is then at

Below: **The A86 machine breaks through**



T&TI'S MACHINERY, MATERIALS & EQUIPMENT REVIEW

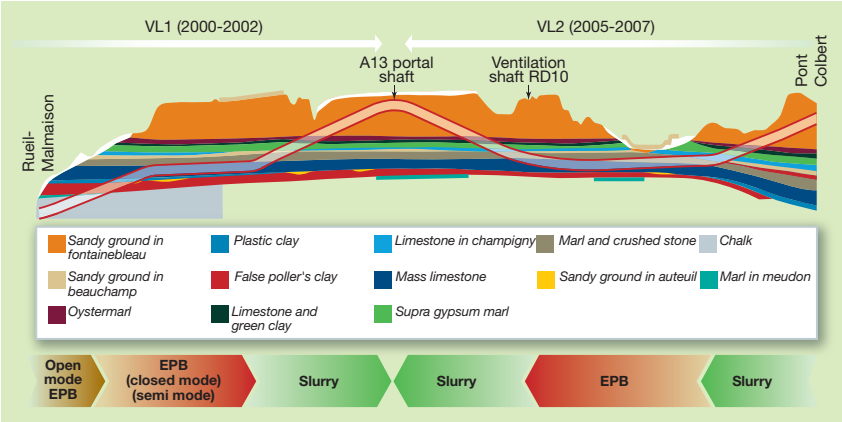
AUGUST 2008

****CALL FOR COPY****

CONTACT US NOW TO BE INCLUDED

To obtain further information about this edition of *T&TI*, or to obtain details of our editorial requirements, please contact us today:
Email: afoley@tunnelsonline.info
Tel: +44 20 8269 7789

COPY MUST BE RECEIVED BY 07 JULY 2008



Above: **Fig 14 - A86 Tunnel alignment**

atmospheric pressure and can be used as a working chamber, only pressurised during face access. To change from EPB to slurry mode, the entire screw casing is moved back, thus clearing the submerged wall opening in the invert and the suction grille below. After this, a specially designed jaw crusher moves from parked position to operational mode.

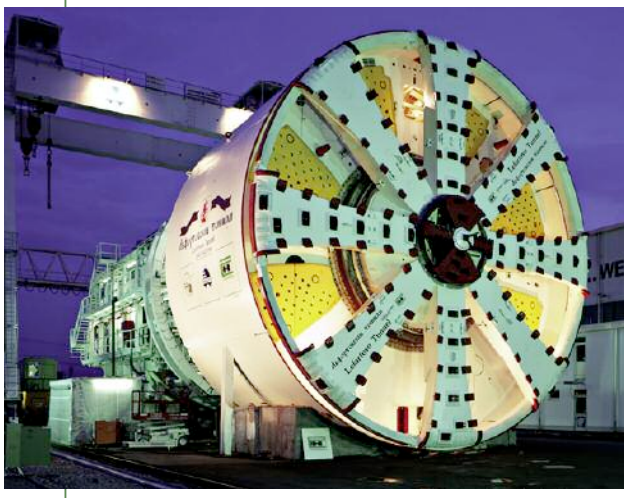
Some of the slurry mode installations, such as the air bubble pressure regulation system or the bentonite circulation systems, can also be used in EPB mode when required. Having the two systems permanently available provides potential synergy.

Apart from the ability to change modes of operation, the TBM also has the following technical key features:

- To cater for EPB mode, installed cutterhead power is 4000kW and the available cutterhead torque is 35000kN/m. Shield thrust is 150000kN, and the designed advance speed is 80mm/min
- The slurry circuit with 1900m³/h flow volume is designed for a mining speed of 50mm/min in slurry mode. The tunnel is runs uphill and the largest difference in height between portal and TBM is 160m. This configuration needed to be addressed in the design of the slurry circuit as, under some conditions, the friction losses in the discharge line are less than the geometrical height between TBM and treatment plant
- A specially designed camera system for the excavation chamber was installed for the first time and successfully tested in semi EPB/compressed air or open mode
- Due to the steep tunnel gradient of 4.5% rubber tired vehicles were used for segment and grout transport. At the tunnel portal a semi-automatic loading station for the vehicles was installed loading one complete multi stack truckload at the same time, which together with a quick unloading system in the gantry reduced the turnaround cycles

The pre-cast invert slab elements for the final lower road deck were installed 200m behind the trailing gear, concurrent to the advance of the TBM. In November 2000, the machine started excavating the VL1 tunnel (figure 14) in open mode EPB configuration. The first 150m in an incomplete starting configuration through chalk containing a high amount of flint was excavated in two-shift operation, quickly reaching mining speeds of 80mm/min. After having installed the TBM and portal systems in their final configuration, the operation was changed to three shifts.

Following a fire in the rear section of the tunnel in 2002, mining activities were halted for three months. By October 2002, the TBM had operated in open mode, closed mode EPB with face pressures of 1-2 bar, and semi EPB mode. The semi EPB mode proved to be the most appropriate method for excavating the stable but water bearing material, using the compressed air to control the water and achieving dry excavated material.



Left: **The 14.2m diameter Lefortovo Mixshield, before it was shipped to Moscow, Russia**

With the ground conditions changing into Fontainebleau sand, the machine was changed in-tunnel to slurry mode and operated in that mode for one year achieving mining speeds of 50mm/min. The breakthrough of the first tunnel was in October 2003. The TBM was disassembled, transported and reassembled at the Pont Colbert starting portal for the VL2 tunnel.

For the VL2 tunnel the TBM began excavation in slurry mode. Immediately, around 10m after the portal, a major six-lane motorway had to be passed beneath with shallow cover. Launch and passing under the freeway was completed after just nine days with no problems. After 1.2km in slurry mode, the TBM was changed back to EPB mode, and after passing an escape and ventilation shaft at the deepest point of the VL2 tunnel the TBM mode was changed back to slurry again. The machine arrived at the portal in August 2007.

Conclusion

Initiated by the requirements of numerous large scale projects around the world, the development of Mixshield technology has taken major steps forward, as illustrated in this and the previous article (*T&TI*, May p35). Numerous additional features are also currently on the drawing board or being used for the first time. These include:

- Advanced wear detection systems for cutting tools and structure
- Positive ground support of the tunnel wall along the shield skin
- Advanced ground improvement scenarios for closed mode from within the machine
- Total integration of the whole package of above ground and underground measurement, process and alignment control data for a controlled boring process (CBP)
- Approaching diameters of 18m to 20m
- Fully variable, multi-mode concepts (EPB/HD slurry/LD slurry)

The ability to handle high water pressures, the potential for crusher installation, low power requirements, high accuracy of face pressure and settlement control, and favourable face configurations, are just some of the current advantages of Mixshield technology. The combination of these advantages along with the ability to change modes of operation, brings the concept close to combining the best of both worlds. Nevertheless, there is also still huge potential for future development of the technology, that will see even greater tunnelling challenges conquered. T&T

T&TI'S MACHINERY, MATERIALS & EQUIPMENT REVIEW

AUGUST 2008

****CALL FOR COPY****

Tunnels & Tunnelling's annual "Machinery, Materials & Equipment Review" has become the definitive guide to manufacturers and suppliers in the international tunnelling industry.

Every August, *T&TI* dedicates its pages to product updates, new developments and project news from manufacturers and suppliers. This is a great, free-of-charge, opportunity to update the industry on your company's products.

CONTACT US NOW TO BE INCLUDED

To obtain further information about this edition of *T&TI*, or to obtain details of our editorial requirements, please contact us today:
Email: afoley@tunnelsonline.info / Tel: +44 20 8269 7789

COPY MUST BE RECEIVED BY 07 JULY 2008

Products

Servicing South Africa's new rapid rail link

The Gautrain Rapid Rail Link is a new 80km long high-speed rail project in South Africa that will link Johannesburg and Pretoria (Tshwane) with the international airport. The total tunnelled length of the link is almost 16km, with 13km of this being constructed by drill and blast methods and 3km by a 6.68m diameter Herrenknecht EPBM.

In September 2006, the Bombela International Consortium commenced construction works for the project, which are scheduled to last 45 months.

Servicing the drill and blast tunnelling works are a number of Paus/ITC dumper trucks. These machines were delivered at the beginning of 2007 and have been in use ever since.

Paus/ITC won the contract due to the advantages the Paus Dumpers offer. The Dumper PMKT/ITC 10000 stands out due to it small width at a working load of 20t. The truck has a sturdy driver's protection roof (a closed cabin is available as an option) and a 180° rotatable driver's seat with two separate control desks for driving in each direction.

In an unloaded state the design of the skip allows full view to the rear, so the driver can drive into the tunnel. In loaded state he turns his seat and drives out forward without turning the truck around, so that even in a confined area two vehicles can drive past each other.

"We are proud of taking an active part in this large project with our systems," say Carlo Bretz, managing director of ITC, and Benno Kramer, sales manager and authorised signatory, of Paus.

Paus Maschinenfabrik
Web: www.paus.de
(www.itcsa.com)

Upgraded airflow measurement

Mine & Process Service, recently introduced its new PMA-2008 Pocket Mining Anemometer. The anemometer is an upgrade to and will replace its popular PMA-2001 Anemometer, which was introduced in 2002. The PMA-2008 Anemometer is very recognisable with its new, bright orange enclosure.

The PMA-2008 Anemometer includes several enhancements, such as multiple display functions, an audible signal every 15 seconds during the 60-second counting cycle and reflective labelling on its protective case. It is approved as intrinsically safe by MSHA.

Mine & Process Service
Web: www.go-mpsinc.com

Products

Greener repairs for UK

Ferro Monk Systems, one of the UK's leading wastewater asset rehabilitation specialists, has become the first UK approved contractor to use Ultracoat - a 100% solids epoxy sprayed coating system. Ultracoat is a well established process for re-lining, coating, and upgrading existing structures. Containing no Volatile Organic Compounds (VOCs), it is suited to confined spaces, has a high-resistance to H2S attack and can be applied to damp substrates.

Ultracoat has been successfully installed to renovate many miles of pipes, tunnels, tanks and chambers. It is also the only coating approved by the US Navy for potable water, fuel, oil and sewage applications.

Danny Heffernan managing director of Ferro Monk said: "An environmentally friendly solution, Ultracoat can be sprayed onto a wide variety of surfaces, with the added bonus that surfaces can be coated whilst damp".

Ferro Monk Systems
Web: www.ferromonk.co.uk

HDD to clean up North Sea holms

The holms, or tidal mudflats, off the North Sea coast of Germany, act as breakwaters for the mainland. They calm the sea, stabilise sand banks, and are an important habitat for wildlife. Among the 10 holms in the North Sea is Oland, with 37 inhabitants, and Gröde, with just 18 inhabitants.

Classed as nature preserves, any building work on the holms is strictly controlled: "The construction of a foul water pipeline and sewage plant on both holms is no exception, despite being designed to assist nature preservation," commented Martin Woltering from the engineering firm IVERS GmbH.

Oland and Gröde are the last two holms where sewage is stored in home-owned cesspits. The material has to be emptied from the pits on a regular basis and transported to the mainland. However, this will soon be a thing of the past, once the new sewage plants are finished this year.

The sewage pipes and pump pits on Oland are now installed, while work is still underway in Gröde. Construction of the sewage plants will only commence once this work has been completed.

Specialist company Benno Paasch are installing the 63mm sewage pipes, together with a cable protection pipe ND 50 for power supply to the pump shafts, using HDD methods. Paasch employed a small, Grundodrill 4X self-driven HD rig for the bores, supplied by Tracto-Technik. This flexible, space-saving rig is ideal for transportation to and use on the small islands. The 4t-rig is also ideal for work in these ground conditions, with just a water/polymer mixture required to support the bore.

The water is circulated inside a MA09 mixing system with a 1000l tank. A specially widened bore head produces the pilot bore with a diameter of 140mm, which is expanded to 150mm when pulling in the pipe lengths. The longest bore has a length of 80m. Whenever possible, pump shafts are used as start and target areas.

All in all, the holm inhabitants have been very satisfied with the un-obtrusive trenchless installation process. By end of the year, the building measures should be completed on Oland and Gröde.

Tracto-Technik
Web: www.tracto-technik.de

View of Oland and (inset) the Grundodrill 4X during a pilot bore

Convergency compatible support systems

E Schneider, of the Institute of Construction and Material Sciences at Innsbruck University, Austria, and M Spiegl, of SSP BauConsult GmbH, discuss yielding support systems and their possible applications

Convergency compatible yielding support systems are well established in conventional tunnelling. They were developed to take advantage of the fact that the load on a tunnel support is reduced when controlled convergencies are allowed. This principle not only applies for drill and blast tunnels but also for gripper type TBM tunnels where conventional support like steel ribs, shotcrete and anchors are used.

Recently proposals have been put forward by various parties to combine the idea of convergency compatible support with prefabricated concrete segmental linings, installed behind shielded TBMs. This paper gives an overview of the current, and future, developments in this field.

Geotechnical background

It is generally accepted in tunnelling that controlled convergencies reduce the load on the tunnel support. This phenomenon can be visualised in a diagram showing the dependency between radial stress and radial deformation (figures 1 & 2).

The diagrams have been published in various forms by different authors beginning with Fenner (1938) and Pacher (1964)[1]. Other prominent authors are Lombardi, Egger and Seeber. For practical use in the design of tunnel support and lining numerical solutions have been developed by some of these and other authors.

Convergency support-systems

The most popular application of the above mentioned principle is NATM (New Austrian Tunnelling Method). It was developed in the 1960's by Rabcewicz, Müller and Pacher. Their ideas revolutionised the design and construction of tunnels the world over. It was only natural that such success led to discussion of authorship, although there is a common understanding now that the development of NATM was mainly an Austrian achievement even if it was based on "inventions" made elsewhere and contributions from other countries.

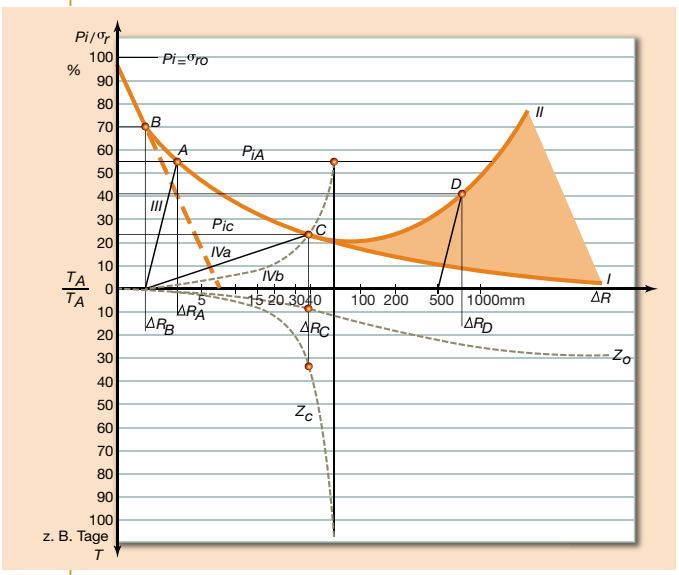
Obviously it is more productive to look ahead than to dig over the past and one way of doing this is to concentrate on finding solutions for a convergency compatible support for TBM-bored tunnels with a segmental lining.

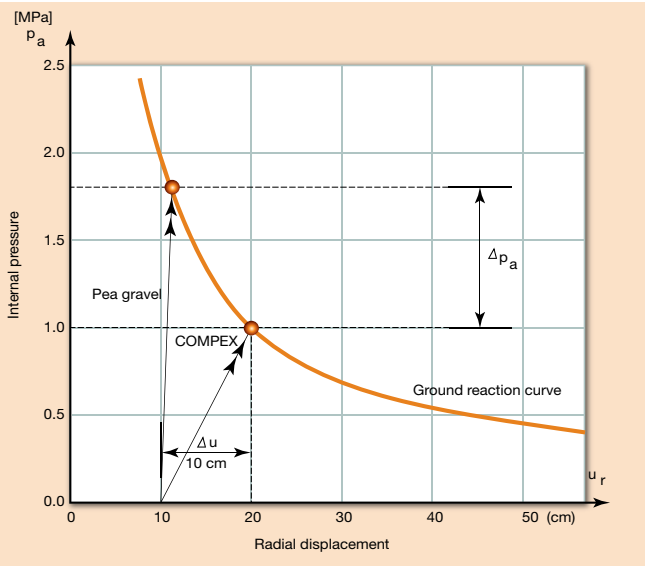
Before going further, the authors would like to remark on how the principles of NATM are applied in different countries. For tunnels in shallow depth the main support measure is nearly the same everywhere, namely reinforced shotcrete. For tunnels with higher overburden, the Swiss use convergency compatible steel ribs as the main support, whereas the Austrians use mainly shotcrete and rockbolts. Longitudinal open slots in the shotcrete shell or compressible elements in various shapes, which help to prevent fractures in the shotcrete shell, have been common practice in Austria since the 1970's. Only recently engineers from other countries have begun to recognise their advantages.

A different development, which some consider a logical development of NATM – an interpretation the authors do not share – has taken place in Italy.

Lunardi, the inventor and promoter of the ADECO.RS system (Analisi delle deformationi controllate nelle rocce e suoli[2]) emphasises the importance of maintaining a three-dimensional stress-situation at the tunnel face. In contrast to

Left: **Fig 1 – Ground and support reaction curves according to Pacher[1]**
Right: **Fig 2 – Reduction of load on segmental lining by use of COMPEX mortar**





Austria, where this principle is also considered as important but for practical reasons is given lower priority and where the general method is to excavate and support a tunnel in squeezing rock by sequential steps, the ADECO.RS-method uses full face excavation under all conditions. This is made possible by controlling deformations of the face using long fibre-glass anchors and by installing a full circle of heavy, rigid support/lining immediately after opening the face. Apart from geotechnical doubts the authors have some reservations about the claimed cost-saving effects of this method.

Recent developments

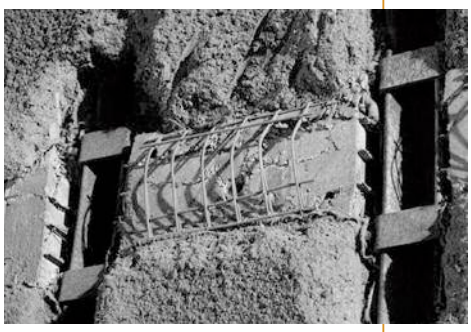
A new support solution for conventionally excavated tunnels in severely squeezing rock was developed at the Sedrun Lot on the Gotthard Base Tunnel. Inspired by ideas from Italy and by methods developed in German coal mines, where squeezing rock prevails, the Swiss engineers designed a convergency compatible steel support system that, combined with long face anchors, successfully permitted full face excavation of the Tavetscher Zwischenmassiv, the most critical zone of the whole project[3].

A similar solution has been applied in the Saint Martin-La Porte access gallery of the Lyon-Turin Base Tunnel by Barla and Panet[4]. There, heavy steel ribs with sliding joints were combined with a 200mm-300mm thick shotcrete layer. Similar to solutions developed in Austria, where compressible steel elements intercept the rigid shotcrete shell, highly deformable concrete elements were installed. These helped to prevent cracks and fractures in the shotcrete shell, caused by overloading.

Convergency for gripper TBMs

In North America, where tunnelling with gripper TBMs has a long history of success, the preferred means of support is steel ribs with wooden lagging. In Europe, until recently, many engineers thought that steel bolts with wire mesh completed by shotcrete is the most appropriate measure behind a gripper TBM for all conditions, including squeezing. The problem with this is it will only work if the rock is not too sheared or squeezing. Many tunnel designers and contractors have now realised that in squeezing rock, full circle steel ribs are a much better solution. Tunnels in very difficult ground like the Walgau, in Austria (1981-1984), or Evinos, in Greece (1992-1995), have been driven successfully using a combination of rigid full circle steel ribs and shotcrete.

In the 1990s an even better solution - yielding steel ribs with sliding joints - was introduced at the Vereina Tunnel, in Switzerland, and became an immediate



Above, left: **Gotthard's Sedrun section;** Right: **Saint Martin-LA Porte access gallery**

success[5]. Amazingly it took more than ten years before a further development of this system was made. There is little doubt that squeezing sections, such as those at the start of the Faido-Sedrun heading of the Gotthard Base Tunnel, could not have been constructed by open TBMs without this kind of yielding support. In both projects steel ribs with sliding joints were installed right behind the cutterhead support and completed by an additional shotcrete layer some 50m-60m behind. Depending on the local conditions systematic bolting and shotcrete were applied additionally right behind the cutterhead support.

Convergency for segmental lining

With the increasing application of shielded TBMs in rock-tunnels, ideas for convergency compatible segmental lining systems appeared. One of the first was a proposal by a British tunnelling contractor, who applied for a patent in the late 1970's[6]. Since then numerous have been published but so far none have come to fruition. The proposals can be classified into three categories (figure 3):

- Installation of compressible elements in the longitudinal joints
- Ribbed-segments with outer recesses
- Annular gap filled with compressible mortar

Compressible elements

The idea to install compressible elements in the longitudinal joints originates from conventional excavation. Long before such systems were applied in tunnelling they were used in coal mining in the shape of "Quetschhölzer". Today's deformable elements are made from steel or concrete. In order to provide an appropriate reaction against the load, they are designed so that the characteristics of their stress-deformation curve match the load-bearing capacity of the support.

Though this looks fine in theory, no one has as yet installed compressible elements in combination with a segmental lining erected behind a shielded TBM.

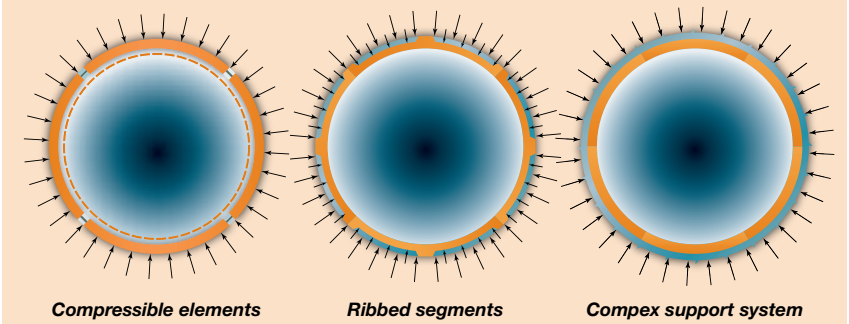
The idea for the ribbed-segments (Vigl[8]) originates from observations in the Walgau and Evinos Tunnels. On both projects, plastic deformation over long sections of the rock-mass was observed between the rigid steel ribs. For several days, before the support was completed by shotcrete, the ground was allowed to creep inward. The ribbed segments follow the same principle. The ribs can be considered as the rigid members of the system. The recesses give room for radial deformation of the surrounding rock mass.

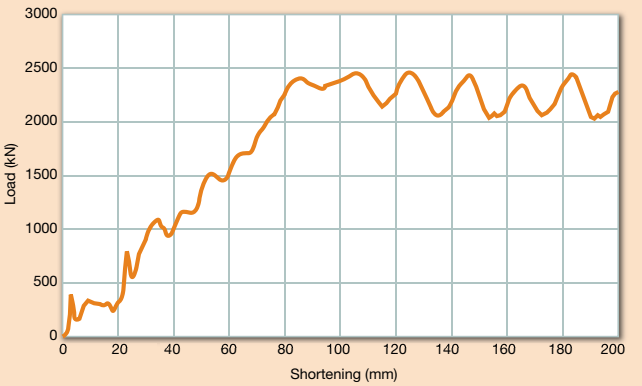
As mentioned the idea to fill the annular gap between the segments and the rock mass with compressible material was first published in the late 1970's. The patent applied for;

"...a deformable intermediate layer of a compressible material between the tunnel lining and the surrounding ground..."

Unfortunately for the inventor this proposal remained unheard of for more than 15 years before a group of engineers and supply companies headed by

Below: **Fig 3 – Overview of the systems**





Above, left: Fig 4 – Load displacement diagram for a project designed group of 4 LSC (B Moritz 2008); Above, right: Section through a yielding element[7]

D2Consult from Austria launched a research project aimed at the; "development of a fully mechanised tunnelling system with a single shell lining made from prefabricated segments of reinforced concrete for application in tunnels with high overburden."

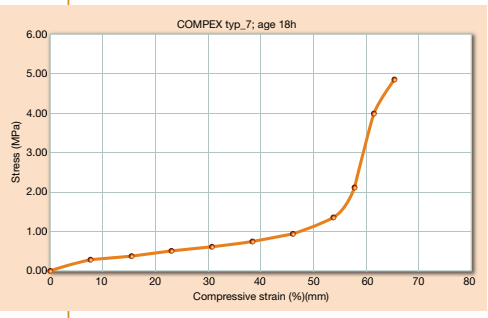
Compressible elements designed for installation in the longitudinal joints, sealing-systems, membranes, connecting bolts, pressure relieving valves, yielding anchors, amongst others were developed. A minor part of the project was the development of a compressible mortar for filling the annular gap.

Recent developments

Independently, and unaware of earlier developments, an Austrian engineer, K Rotter from Innsbruck, began to develop a method by which long sections of squeezing rock could be excavated by shielded TBM and lined with precast concrete segments. Research was two tiered; the development of a new type of TBM capable of dealing with squeezing conditions; and the development of a compressible mortar. After intensive discussions with TBM manufacturers and the authors of this paper the first was abandoned and efforts were focused on further developing a compressible mortar, on which Rotter had already spent considerable time and money. In the 1990's he was successful in finding two industrial partners to join him. One was a cement manufacturer, the other a polystyrene technology company. A series of lab tests and large scale mixing and pumping tests were performed and the result was a near perfect material named COMPEX-mortar, which suited all requirements[9].

It came as a surprise to the Rotter-group, when it found a paper in the Tunnelbautaschenbuch 2008 by German company Hochtief presenting a very similar development[10].

Below: Fig 5 – Stress deformation diagram COMPEX (type 7) (Schretter & CIE)



COMPEX Support System

The mortars developed by the two groups have similar characteristics. They are both formulated on a cement-based binding material and aggregates made from polystyrene. The properties of the mortar are such that under confined lateral expansion conditions a minimum compression of 50% is achieved without cracking or fracturing. The stress-deformation curve starts with an initial increase followed by a plateau and ends with a final increase to the maximum load.

The load bearing capacity of a tunnel support, or lining, is normally determined by its segments. Through modification of the mortar it is possible to adjust the compressive strength accordingly in a range between 1 and 5MPa by 50% compressive strain. The progress of stiffening and hardening of the mortar can be adjusted to the deformation characteristics of the rock-mass. It is possible to modify the binding-material in such a way that the mortar remains compressible over a substantial length of time, varying from one to around 21 - 28 days according to requirements (figure 5).

Filling the annular gap with compressible mortar has the following advantages:

- Fast and if required gives active support of the tunnel roof and walls
- Homogeneous bedding of the segments over the full radius
- Avoiding point loads on the segments
- In combination with a defined overcut of the TBM the thickness of the gap and the allowance for radial deformation can be adjusted to the expected deformation
- The load on segments is much reduced

Applications

It was the first goal of the development to allow TBM excavations in squeezing rock. Such sections are expected in most of the Alpine Base Tunnels such as the Brenner, the Koralm and in the Lyon-Turin Base Tunnel. It is expected that with the application of the COMPEX support system major sections of this could be undertaken. The subsequent lining by concrete segments will allow higher advance rates than conventional excavation or by gripper type TBM.

Another application of the COMPEX support system could be in swelling rock. This type of rockmass behaviour is found in many tunnels in the Swiss Jura and in the Schwäbische Alb in Germany.

Processing problems

Major problems to be solved before the COMPEX System can be practiced are:

- Mixing of mortar
- Pumping of mortar
- Holding of pressure (sealing problems)

Mixing is a problem, because the polystyrene aggregates have a very low density of 28 to 60kg/m³ and the water-cement ratio should be kept below 0.4 to guarantee good long-term stability and maximum strength. To provide good handling the mortar should have a setting time of a minimum three hours. For the segmental lining stability of the segment lining the mortar should start to stiffen as soon as possible after being filled in.

To meet these demands the grain size of the aggregates was chosen carefully. The type of cement chosen was fine grinded with a Blaine-value of approximately 5.000cm²/g. Furthermore a combination of fast and slow reacting cement plus a number of additives was developed.

The problems related to mixing could be solved by the use of special mixers and a special cement. For compressible mortar a continuously working screw or hose-type pump is considered the most appropriate.

Filling the annular gap with mortar requires a seal between the outside of the shield and the rock surface. This problem required extensive discussions with TBM manufacturer Herrenknecht until a viable solution was found.

Summary

Convergency compatible support systems are well established in conventional tunnelling. Solutions for convergency compatible systems in tunnels driven by shielded TBMs with subsequent segmental lining are still under development.

One solution - the installation of deformable elements in the longitudinal joints - is unlikely to make its way from use in conventional tunnelling into mechanised tunnelling.

Of the two other remaining solutions – ribbed segment with recess, or compressible filling of the annular gap – the latter is the more promising one. Its application will facilitate tunnel driving by TBM through sections of squeezing rock.

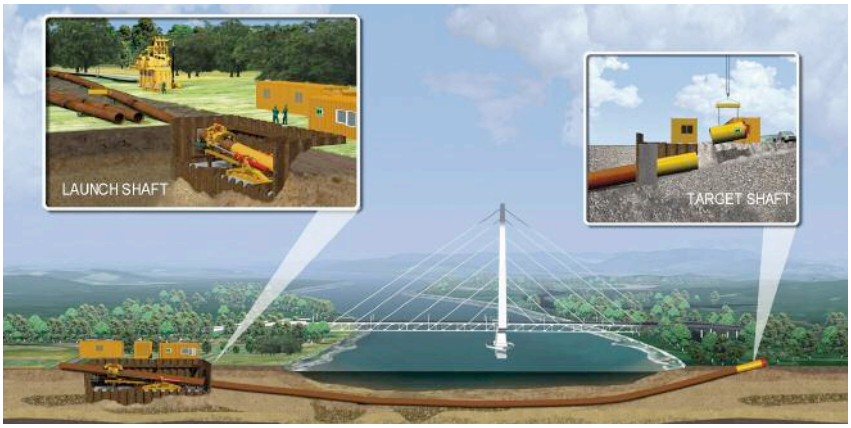
REFERENCES

1. E Pacher, 1964. Deformationsmessung im Versuchsstollen als Mittel zur Erforschung des Gebirgsverhaltens und zur Bemessung des Ausbaues; Felsmech und Ing. Geol., Suppl. I.
2. P Lunardi, 2000. The design and construction of tunnels using the approach based in the analysis for controlled deformations in rock and soils. *T&T International* (Suppl.).
3. K Kovari, H Ehrbar, 2008. Die druckhaften Strecken im TZM-Nord des Gotthard Basistunnels; Vortrag beim Swiss Tunnel Congress
4. G Barla et. al. 2007. Lessons learned during the excavation of the Saint Martin la Porte access gallery along the Lyon-Turin Base Tunnel. Internationales Symposium Brenner Basistunnel und Zulaufstrecken, Innsbruck
5. R Amberg, 1993. Detailed design Vereinatunnel lot T4, Northern Section; Sargans
6. J Mowlem, 1979. UK Patent application GB 2013757 A
7. B Moritz, 1999. Ductile Support System for Tunnels in Squeezing Rock. In Riedmüller, Schubert, Semprich (eds) Gruppe Geotechnik Graz, Heft 5, Graz University of Technology
8. A Vigl, 2007. Investigations for a Convergence Compatible Lining System. FELSBAU
9. E Schneider, K Rotter, A Saxer, R Röck, 2005. Compex Support System – Komprimierbarer Ringspaltmörtel zur Bewältigung druckhafter Gebirgsbereiche bei TBM-Vortrieben mit starrem Tübbingausbau. FELSBAU
10. Taschenbuch für den Tunnelbau 2008; Deutsche Gesellschaft für Geotechnik e. V.

Since this method provides higher advance rates than conventional methods of excavation and support its application will save cost and time. For huge projects like the Alpine base-tunnels in Austria, Italy and France and tunnels in Jurassic formations this could be of great importance. T&T

Trenchless installation and replacement

Just when it looks like an industry has reached its developmental height, along comes an innovation that breaks the mould, Contributor, Ian Clarke, reports



Above: **A schematic of the Direct Pipe installation technique recently developed by Germany's Herrenknecht**

Renowned for its expertise in large diameter TBMs, pipe jacking and microtunnelling equipment, and more recently larger capacity horizontal directional drilling (HDD rigs), Herrenknecht, in the early part of 2007, launched its Easy Pipe system which, as covered in the *T&TI* Trenchless Review of 2007, uses retractable/reusable jacking pipes in the tunnelling process to enable product pipe to be pulled into a microtunnelled bore.

Now the company has launched Direct Pipe, which is designed to utilise the power and accuracy of the microtunnelling technique to lay larger diameter, continuously welded steel casing pipes directly into the ground in a single operation.

The accuracy of microtunnelling has long been an established fact within the tunnelling industry and the development of the Direct Pipe method, which is something of a combination of microtunnelling and HDD techniques, was not only based on a need to create of a one-step pipe laying method but also on the provision of an efficient alternative to existing methods.

Below: **The new combination pilot auger/HDD rig from Perforator**

The technique required was one that was able to minimise the geological risks (e.g: bore-hole collapse that may occur using HDD). With Direct Pipe steel pipelines can now be, for the first time, pipe jacked efficiently and quickly in one process without the need for large target shaft areas for pipe preparation and storage prior to pull-in. The direct installation of the pipeline allows for continuous drill-hole support preventing potential borehole collapse.

The microtunnelling shield is controlled remotely as it would be on any standard microtunnelling installation with the navigation system giving the same level of alignment accuracy over the course of the bore. What is different with this technique has been the development of the Herrenknecht Pipe Thruster, which enables the continuously welded pipe to be used as the jacking pipe to advance the shield through the ground. On arrival of the cutting head at the target shaft it is removed leaving the casing pipe installed awaiting installation of the product pipes or cables.

In a similar vain, that of combining recognised technologies, Perforator has developed a modification to its standard PBA85 guided auger boring machine to enable it to be used like an HDD rig. This new set up enables the rig to be used from its usual start shaft to install a very accurate pilot bore using a monitor, an optical system with CCD camera and a diode target plate. However, instead of using auger casing and excavation to enlarge the bore and install the pipe from the jacking shaft, a modified drive component allows the pilot rods to be attached to a reamer head, which is then pulled back through the bore to open the hole to the correct size and install the pipe from the reception pit end as with HDD operations. The basic PB85 pilot boring system is a compact, multi-purpose thrust boring machine designed for pipe line, house connection and steel pipe jacking installations of up to 610mm o.d., as is the new PBA85V with HDD ability. The basic machine is used in combination with re-usable or lost steel casings. The machine bed and additional extension frames allow the use of casings up to 6m long.

The very specific difference between the standard PBA85 rig and the new PBA85V system is that, on the 'V' version, a gearbox normally used in the Perforator PBA150 rig is fitted. This allows the 'V' unit to offer double the torque capacity of the basic unit.

The directional drilling unit can be fitted to the system and utilises the twin wall pilot rods of the standard PBA 85 system, which are designed to accept high pressure HDD fluids, to create the initial bore. Subsequently, the high pressure drilling fluids are delivered to special rotary reamers using a purpose built pump tank and mixer unit with a 2,000 litre capacity.

Towing attachments and swivels have

Above: **The new 84/96-1300 NG auger boring system from American Augers**

been specially designed to work within the PBA85V's 65 tonnes of pullback capacity to enable the pull-in of the product pipe.

With more than 37 years of experience in the manufacture of auger boring equipment, American Augers has announced the release of the new 36-600 NG Horizontal Earth Boring Machine.

The standard features of the 36-600 NG include: A DEUTZ F6L914 85kW turbo diesel engine, a Spicer 5 Speed Constant Mesh Transmission, maximum rotary torque of 175,139Nm, and a working range from 305 to 914mm casing diameter.

The 'next generation' design benefits claimed for the machine also incorporate the Quik Tran fast return system, available exclusively from American Augers, as it provides up to 4.5t of push/pull at high speed, and the Quik Split design feature that allows the machine to be separated into sections for faster and easier lifts into and out of the working pit.

Operators of the 36-600 NG will also enjoy an increased ability to pull auger, steering rods, and push product, improved visibility to the master pusher, low centreline and wide stance that provides substantial machine stability.

As well as the 36-600 NG, American Augers also recently introduced the 84/96-1300 NG system designed to bring a greater combination of working diameter and maximum power to the auger boring market. The main advantage of the 84/96-1300 NG is that it will allow contractors to perform larger diameter installation projects a much lower cost, and achieve success with projects that were only possible before with costly microtunnelling machines.

The standard model is designed with a 223kW Caterpillar C-7 Tier III Diesel Engine, and a seven-speed Eaton T14607A Transmission. These features provide the machine with 5,777kN of maximum thrust, and 304,079Nm of maximum torque. The 84/96-1300 is also equipped with a 125mm hex, and has a working range of 610 to 2,438mm.

Above: **The TERRA-JET 7520 D is the latest addition to the range of HDD systems manufactured by Terra**

HDD

Developments have also continued apace in the Horizontal Directional Drilling field. For example, Swiss manufacturer Terra has developed a new Horizontal Directional Drilling (HDD) machine the TERRA-JET 7520 D, which claims to set new standards in the 20t HDD rig class.

The TERRA-JET 7520 D has the capability to install directional bores of up to 400m long and 800mm diameter, depending on ground conditions. Due to the low engine speed, of only 1,850rpm, the machine has a 'supersilent' operation. The machines torque and pullback force are produced by separated hydraulic circuits. Therefore the maximum torque of 7,750Nm and the maximum pullback force of 195kN can be used simultaneously under full load. The multifunctional joystick activates during back reaming and pipe pulling, with the TERRA-JET 7520 D being equipped with a new second generation ADBS. This patented Automatic Drilling and Backreaming System (ADBS) automatically adjusts the machine's working speed within milliseconds in relation to the prevailing ground conditions. The drilling fluid volume is 185 l/min at a maximum fluid pressure of 85 bar. Optionally the drilling fluid volume may be increased to 370 l/min. The machine's rod changer allows very fast drill rod changes with one rod magazine holding 120m drill rods.

Also in the HDD sector, Tracto-Technik recently launched the new GRUNDODRILL 15N HDD rig which incorporates a powerful combination of the TT Group's latest technology and worldwide user experience. Precision engineered, the GRUNDODRILL 15N's rigid construction easily handles its 7,000Nm of available torque and 167kN of thrust and pullback. During the drilling process the rig can be quickly configured using the touch screen control and provide all functions with the required power, to suit the toughest ground types, up to the maximum values given.

The GRUNDODRILL's dynamic impact unit, provides an additional percussive impact value of 28t at a frequency 0-1,500 impacts per minute. This unique patented TT feature provides fast, accurate drilling in the hardest of ground types.

A facility on the GRUNDODRILL 15N automatically identifies a full or empty bay in the drill rod box which is advanced accordingly. Both the rod loading and connecting of the drill string are fully automatic. The rod box has the capacity to store seventy (70 No) 3m long drill rods, to give a working distance of 210m. From a pilot bore of 115mm diameter, pipes up to a diameter of 500mm can be installed, subject to ground conditions, with 300m bore lengths being possible.

With the rig's extremely slim profile, just 2m wide, and variable mast angle inclination, from 0° to 30°, drilling is possible in the tightest locations. The drill stem axis is positioned 900mm in from the side, to allow drilling work in close proximity to walls or hedgerows, etc. The drilling process is controlled via twin multifunction joysticks positioned to operate and control all functions whilst settings and real-time values are monitored on the GRUNDODRILL's space saving colour display function screen. Remote, real-time telemetry, diagnostic and service menu operator support is a standard feature.

Below: **The GRUNDODRILL 15N is the latest HDD rig to be brought to the market by Tracto-Technik**

Above: **Ditch Witch has recently upgraded both the Mach 1 and All Terrain versions of its well-established Jet Trac JT4020 HDD rigs**

In the USA, American Augers has had a busy year with the launch of several new drill rigs, auger borers and mud handling systems. Included in the recent product releases has been the DD-440T Maxi-Rig, which is being claimed to bring a new era in track driven directional drilling.

The DD-440T provides 200t of maximum thrust/pullback, and utilises it with excavator track driven mobility. The carriage system provides, a rack and pinion, two pinion drive with adjustable force limiter. The state-of-the-art rotary system includes a three pinion and gear drive with infinitely variable torque, up to 80,000Nm of maximum rotary torque, a rear mounted mud swivel that provides up to 2,460 l/min flow, slip spindle, and a 75mm fluid course.

Other standard features include: 10°-18° drill angle, triple jaw wrenches with a 305mm separation, wrenches that travel the full length of the thrust frame, 200kNm of maximum breakout torque, 136kNm of maximum makeup torque, H-Beam type front and rear safety hold down system with struts, removable wrenches for lighter transport weight, and the ability to utilise Range II drill pipe.

A further addition to the range is the DD-880. This large maxi-rig style for horizontal directional drilling is very well suited to perform large diameter, or long length pipeline and utility installation projects.

The DD-880 provides a maximum 400t thrust/pullback capability as well as up to 136kNm rotary torque. The Standard unit is equipped with a four (4) rack and pinion carriage drive system with adjustable force limiter, 100mm diameter fluid course for increased down hole hydraulic power, triple jaw wrenches with 300mm separation, and a maximum carriage speed of 40m/minute.

Also recently designed, manufactured and launched by American Augers is the new DD-9014 HDD rig, which is a self contained drilling system that features a field-proven design, mobility and flexibility, on the toughest trenchless projects all over the world. According to American Augers the machine brings with it performance, durability, and low down time, the keys to profitable operation.

The standard DD-9014 offers what is claimed to be the best design in mid-size HDD engineering, as this unit comes with a Caterpillar 230 HP (171.1 kW) C-6.6 Tier III Diesel Engine, 40.8t maximum Thrust/ Pullback, Rack and Pinion, (4) Pinion Carriage Drive with Adjustable Force Limiter, and 18,300Nm maximum Rotary Torque, which allows the machine to turn larger size reamers on long distance bores.

The company has also launched the P-500 G2 mud pump, which is a stand alone mud system designed for use with mud motors, large reamers, or whenever more mud volume is needed down hole. Standard features are a Caterpillar C-15 475 HP diesel engine, and a mud pump that has an estimated output of some 1,892.5 l/min flow at 105.5 bar.

The Ditch Witch organisation also announced a significant upgrade to two of its most rugged and powerful horizontal directional drilling (HDD) machines: the JT4020 Mach 1 and JT4020 All Terrain.

Both units are now equipped with a welded, double rack-and-pinion thrust drive system designed to withstand the rigours of long bores in tough soils. This new feature further enhances the reputation of these compact workhorses as some of the most durable and productive in their class.

The rubber-track mounted JT4020 Mach 1 features a 4.5m drill pipe, and has the power and stability to pull multiple conduits up to 305m in a single pass, assisted by a cruise-control feature that maintains thrust and rotation settings.

The JT4020 Mach 1 also features touch-sensitive, variable-speed, electric-over-hydraulic controls that minimise operator effort, with thrust/pullback and rotation controlled by a single lever.

The JT4020 All Terrain has patented features such as a two-pipe rock-drilling system and an integrated electronic system with cruise control, the 142kW JT4020 All Terrain can efficiently install utilities underground at long range, up to 305m.

The company has also broadened its range of guidance systems and bit ranges with the introduction of the 250R/T locating system and the 720ML New Magnetic Locating System.

Below: **Perforator has developed self grouting pipe bursting equipment to minimise the interaction between the new pipe being installed and the old pipe shards that remain in situ**

Replacement systems

One of the most utilised bursting 'system types' systems is the hydraulic pipe bursting rig, which utilises a pipe pushing/pulling unit to pass a steel rod through the existing pipe from a launch pit to a target pit positioned at either end of the pipe being replaced. One drawback of such systems is that occasionally the broken shards from the old pipe cause damage to the new pipe as it passes through the void created.

To address this situation Perforator of Germany, along with its UK subsidiary, has introduced to the pipe bursting market two new bursting rigs, the RBZ60 and the RBZ160 with pullback capacities of 600kN and 1,600kN respectively.

Working in exactly the same way as traditional hydraulic rod-based pipe bursting systems, the major difference between the new rigs and the old style ones is that, using an independent grout injection system, a cement grout mix is pumped under pressure through a feed line inside the new replacement pipe via ports in the expansion head that are positioned to ensure the grout is uniformly placed around the new pipe as it is towed in.

The grout combines with the old pipe shards and the mix is pushed into the surrounding ground, cementing the shards into place. This avoids interaction between the shards and the new pipe so reducing the likelihood of damage to the newly installed pipe during the pull-in operation.

So as was hinted at previously, in a quest for ever improved performance at the most economic outlay, developments in the installation and replacement sectors of the trenchless technology industry have yet still to peak. T&T

CROSSRAIL

Civil & Tunnelling Engineers

Attractive salary + final salary pension + rail travel

Crossrail is an ambitious plan to deliver a new railway for London. Our vision is to create a world-class affordable railway, deliver effective partnerships and project excellence, with high performing teams sharing a clear vision and clear objectives. This is a once in a lifetime opportunity to make a significant contribution to public transport, and the quality of life, in London and the country as a whole.

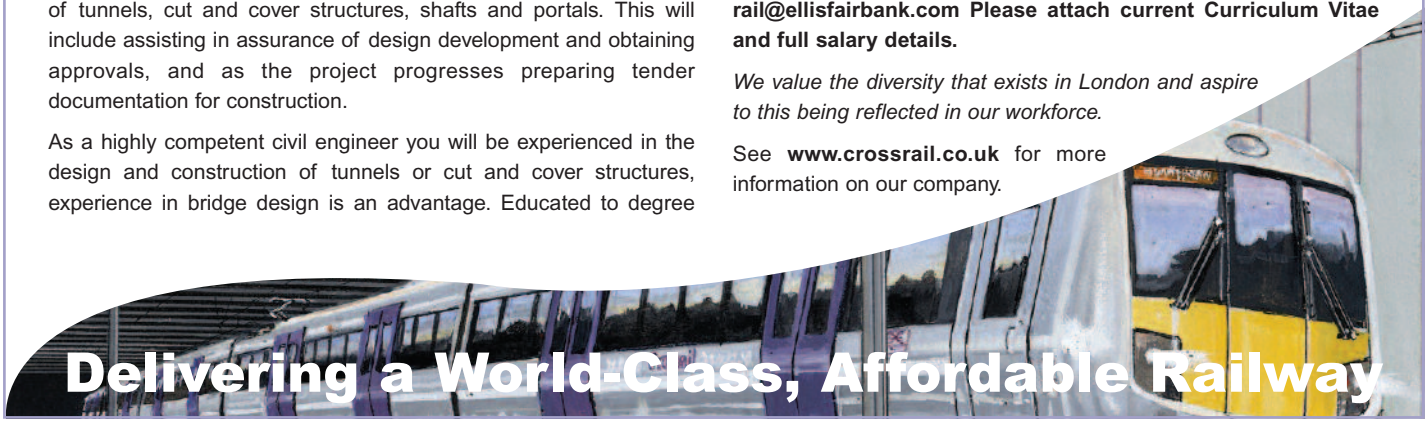
Working within an integrated design team you will lead engineering of tunnels, cut and cover structures, shafts and portals. This will include assisting in assurance of design development and obtaining approvals, and as the project progresses preparing tender documentation for construction.

As a highly competent civil engineer you will be experienced in the design and construction of tunnels or cut and cover structures, experience in bridge design is an advantage. Educated to degree level or equivalent, you will ideally be chartered or working towards chartership. You will need to have knowledge of CDM issues, good computer literacy and possess good communication and team working skills.

If you are interested in delivering this world class transport system, contact our retained consultants at Ellis Fairbank and apply online at www.ellisfairbank.com/pressads when prompted enter the reference PTTL50360JNEW or alternatively email rail@ellisfairbank.com Please attach current Curriculum Vitae and full salary details.

We value the diversity that exists in London and aspire to this being reflected in our workforce.

See **www.crossrail.co.uk** for more information on our company.



COYLE Personnel Plc Recruitment Specialists

REC Recruitment & Employment Confederation

Senior Tunnel Engineer – London to £38K + Car & Benefits

Major new £40m tunnel scheme, construction of 3.0m dia sewer tunnels, shafts and also micro-tunnelling. Experience of shaft sinking and TBM tunnelling essential.

Tunnel Design Engineer – UK - £40K + Benefits

Civil / Structural design of TBM tunnels, underground works and infrastructure projects.

Tunnel Site Engineers – UK - £35K + Car & Benefits

Experience of sprayed concrete, supervising site works on major tunnel construction.

Geotechnical Engineer – UK - to £50K

All levels of experience, design of deep foundations, retaining walls and tunnels.

For more details of these and other vacancies please contact Scott Gisby;
Email: scott.gisby@coyles.co.uk Tel: +44 (0)1622 772509

www.coyles.co.uk/tunnelling

Hunter Personnel

Specialists in Tunnelling, Civils and Construction Recruitment.

Ref:PN3233	**Tunnel Assistant RE**, Turkey	£tbc
Ref:BN430	**Tunnel Site Manager**, Dundee	£25-30phr
Ref:BN429	**Tunnel Agent**, Oxford	£26-32phr
Ref:BN428	**Tunnel Engineer**, Glasgow	£26-29phr
Ref:3191	**Design Engineer**, Gtr London	£35-55kpa + Package

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

UK & OVERSEAS OPPORTUNITIES

Engineering Recruitment

Current opportunities:

- **Deputy RE Bridge & Tunnel Structures** - Abu Dhabi
- **Tunnel Excavation Foreman & Shift Engineers** - Singapore
- **Construction Manager & Senior Tunnel Engineers - Water Project** - London
- **Senior & Section Engineers (Excavated & SCL Tunnel Exp.)** - Surrey
- **TBM Operators (Wirth machine Exp.)** - India • **Tunnels Project Directors** - Hong Kong & Surrey
- **Tunnel Engineers (Immersed Tunnel Exp.)** - Tyne & Wear • **Tunnelling QS** - South East
- **Immersed Tunnel Design Engineers** - Abu Dhabi, UAE or UK Based
- **Tunnel Engineers, Site & Design** - USA • **Tunnel Ventilation Engineers** - UK & USA
- **Tunnel/Underground Structure Design Engineers** - UK, Australia, USA & UAE

REC Recruitment & Employment Confederation

Tel: **+ 44 (0) 207 754 5999** Email: **careers@v-engineeringrecruitment.com**
Web: **www.v-engineeringrecruitment.com**

International Tunnelling Services
Professionals in tunnelling

Building success requires a reliable partner

International Tunnelling Services is specialised in tunnelling recruitment solutions.
We are able to supply qualified personnel of all levels, from loco-operators to project managers.

Do you require effective solutions in terms of cost, speed, quality and cultural fit with your team? Please contact us to discuss your requirements.

E-mail: info@tunnelcrew.nl

www.tunnelcrew.nl

International Tunnelling Services BV
Rivium 2e straat 41b, 2909 LG Capelle aan den IJssel, The Netherlands.
Phone: +31 10 266 94 44 Fax: +31 10 266 94 45

Do you have a vacancy to fill or some equipment to sell?
Call: Gary on +44 (0)20 8269 7849
Email: gtween@tunnelsonline.info Fax: +44 (0)20 8269 7840

WEBSITE DIRECTORY

Dates & Events

23-25 JUNE
2nd Brazilian Congress of Tunnels and Underground Structures, Sao Paulo
With a host of metro, water, and hydropower tunnels underway in South America, this conference will cover 17 tunnelling themes and focus on recent works in the area and will take place at the Centro Fecomercio de Eventos, Sao Paulo. Contact: Tel: +55 11 3522 8164; email: 2cbt@acquacon.com.br

23-27 JUNE
Course on "Tunnel Design and Construction, Brunel University, UK
Now one of the calendar's regular fixtures, the British Tunnelling Society's one stop training shop for tunnel engineers is held again, at London's Brunel University. Contact: Tel: +44 (0) 20 8774 2956; email: christopher.bambridge@mottmac.com; web: www.britishtunnelling.org

25-27 AUGUST
Wireless Communication in Underground & Confined Areas Québec, Canada
The second international conference focusing on original research, innovative applications, or analysis of experiments on site, relating to the niche market of telecommunications in an underground environment (tunnels, metros, mines, etc). Contact: web: www.icwcuca.ca

10-12 SEPTEMBER
12th International Conference "Geotechnica 2008 - Geotechnics, Slovak Republic
The conference organised by the Technical Universities of Ostrava (CZ), Kosice (SK), and Gliwice (PL) focuses on techniques, technologies and monitoring of geotechnical construction. Contact: Nora Badíková. Tel: +421 (0)2 659 36 486; email: orgware@mail.t-com.sk

17-18 SEPTEMBER
IUT '08 International Tunnel Fair Sargans, Switzerland
Held in the Hagerbach Test Gallery (VSH), this tunnelling exhibition sees all the industry's main suppliers gathering in a unique venue. The event also includes live demonstrations and a full seminar. Contact: IUT; web: www.iut.ch

22-27 SEPTEMBER
2008 ITA World Tunnel Congress Agra, India
The 34th ITA General Assembly and Congress will be held at the Hotel Jaypee Palace, in Agra, India. In view of the large scale tunnelling works to be undertaken in the near future in India, there is much scope for agencies within as well as outside the country, to demonstrate their capabilities and network in a truly international gathering. Contact: CBIP; email: sunil@cpib.org; web: www.wtc2008.org

23-26 SEPTEMBER
InnoTrans 2008
Berlin, Germany
This international convention and trade fair for transport technology, including railway infrastructure, interiors, public transport and tunnel construction. The conference has become an increasingly popular addition to the event calendar. Contact: Messe Berlin; Web: www.innotrans.com

6-8 OCTOBER
International Congress 'Building Underground for the future,' Monaco
Organised by the Association Francais des Tunnels et de l'Espace Souterrain (AFTES), the three day event will consider the future use of the underground space with papers presented from all walks of the tunnelling spectrum. Contact: AFTES: email: aftes@snc.fr; web; www.aftes.asso.fr

8-10 OCTOBER
6th Austrian Tunnel Day 2008 Salzburg, Austria
Organised by the Austrian Society for Geomechanics (OEGG), topics for the 6th Austrian Tunnel Day include: Tunnelling in the past and present; Special challenges on large current projects; and a panel discussion entitled "Fair construction execution - economic construction". Contact: OEGG: Tel: +43 (662) 875519; email: salzburg@oegg.at; web: www.oegg.at

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

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

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

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

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

BRITISH TUNNELLING SOCIETY

18 SEPTEMBER: **Kings Cross Station**
Following the annual summer break, meetings resume with a presentation on the complex network of caverns, tunnels and inclined shafts recently constructed at London's King's Cross Station. 5.30pm for 6pm start, at the ICE, Westminster, London.

14-17 JUNE
RETC 2009
Las Vegas, Nevada, USA
Since the first conference in 1972, RETC has been recognised as a leading international tunnelling event for contractors and engineers. Last year, conference attendance exceeded 1500 professionals from more than 30 countries and the exhibition sold out in record time. With a venue of Las Vegas, 2009 is sure to be even more of a success. Contact: SME; web: www.retc.org

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

09-11 SEPTEMBER
EURO:TUN 2009
Bochum, Germany
The 2nd International Conference on Computational Methods in Tunnelling. Organised by the Institute for Structural Mechanics. Contact: Conference Secretariat: Tel: +49 234 32 29051; web: www.eurotun.rub.de

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Tris Thomas, 'Tunnels & Tunnelling International', Progressive House, 2 Maidstone Road, Sidcup, Kent DA14 5HZ, United Kingdom.
Fax: +44 208 269 7840
Email: tthomas@tunnelsonline.info
Web: www.tunnelsonline.info

Contacts

HEAD OFFICE
Progressive Media Markets
Progressive House
2 Maidstone Road
Sidcup, Kent
DA14 5HZ
United Kingdom

WEB
www.tunnelsonline.info

TEL
+44 20 8269 7789

FAX
+44 20 8269 7840

Tris Thomas

Amanda Foley

Gary Tween

David Wildman

HOW TO CONTACT US

EDITORIAL

EDITOR
Tristan Thomas BSc (Hons)
Tel: +44 20 8269 7893 Fax: +44 20 8269 7840
Email: tthomas@tunnelsonline.info

DEPUTY EDITOR
Amanda Foley
Tel: +44 20 8269 7789 Fax: +44 20 8269 7840
Email: afoley@tunnelsonline.info

CONTRIBUTING EDITOR
Patrick Reynolds MEng
Tel: +44 20 8269 7748 Fax: +44 20 8269 7840
Email (copy to both): patrickjreynolds@hotmail.com; preynolds@tunnelsonline.info

DESIGN
Natalie Kyne

TECHNICAL ILLUSTRATOR
Nick Stenning

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

ADVERTISING

GROUP ADVERTISEMENT MANAGER
Gary Tween
Tel: +44 20 8269 7849 Fax: +44 20 8269 7840
Email: gtween@tunnelsonline.info

NORTH AMERICAN MANAGER
Steven Caming - Granite Media Services
Tel: +1 603 447 1187 Fax: +1 603 447 6166
Email: granitemediaservices@yahoo.com

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

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

PUBLISHING

PUBLISHING DIRECTOR
David Wildman
Tel: +44 20 8269 7778 Fax: +44 20 8269 7840
Email: dwildman@progressivemediagroup.com

HOW TO SUBSCRIBE

Tel: +44 845 155 1845 7511 Fax: +44 20 8606 7301
Email: progressive@optimabiz.co.uk

Subscription price (12 months) mailed anywhere in the world: US$226 / £140 / €210 (UK only £94.50). Claims for missing subscribed copies can only be entertained within three months of publication.

HOW TO GET BACK ISSUES

Back issues are available from: Optima WDIS Tel: +44 845 155 1845 7511 Fax: +44 20 8606 7301
Email: progressive@optimabiz.co.uk

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, full colour, high-quality reprints can be supplied to your specification. Please contact the advertising team for full details of this service.

REPRO/PRINT

Tunnels & Tunnelling International is printed at Broglia Press, Poole, Dorset, United Kingdom

Tunnels & Tunnelling International ISSN number 0041-414X is published monthly for US$226 a year by Progressive Media Markets Ltd, Progressive House, 2 Maidstone Road, Sidcup DA14 5HZ, 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.

One breakthrough after another.

Innovation.

For 50 years, nobody's broken more new ground than Robbins.

Robbins invented the first successful tunnel boring machine. That was only the beginning of a long line of firsts: The first Main Beam TBMs. Hard Rock disc cutters. Floating grippers. Double Shield TBMs. Nineteen-inch cutters. Wedgelock cutter mounting. All major innovations that have driven the industry.

And while others try to copy these innovations, they can't duplicate our results. That's because Robbins innovations aren't mere imitations. They're continuous improvements in TBM design, driven by real challenges and lessons learned on more than 700 projects worldwide. Learn more.

Visit us at www.robbinstbm.com.

Robbins

One breakthrough after another.

Innovation.

For 50 years, nobody's broken more new ground than Robbins.

Robbins invented the first successful tunnel boring machine. That was only the beginning of a long line of firsts: The first Main Beam TBMs. Hard Rock disc cutters. Floating grippers. Double Shield TBMs. Nineteen-inch cutters. Wedgelock cutter mounting. All major innovations that have driven the industry.

And while others try to copy these innovations, they can't duplicate our results. That's because Robbins innovations aren't mere imitations. They're continuous improvements in TBM design, driven by real challenges and lessons learned on more than 700 projects worldwide. Learn more.

Visit us at www.robbinstbm.com.

Robbins

A winning combination

The Boomer E-series. A face drilling rig that features the super-fast, prize-winning COP 3038 rock drill. It also introduces the BUT 45, a superb boom that reduces hole deviation, provides extra large coverage area and slashes positioning time between holes by 50%. The result?

A winning combination that significantly cuts tunnelling costs and leads to real operational economy.

Committed to your superior productivity.

Atlas Copco Underground Rock Excavation
www.atlascopco.com

Atlas Copco