DECEMBER 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON TBMS

Includes reports from Dubai's Metro and China's Jinping II project

PRE-CAST LINING

T&TI looks at some recent developments in the field of pre-cast segmental lining

SWITZERLAND: BREAKTHROUGH IN THE JURA MOUNTAINS.

The Herrenknecht Single Shield TBM S-397 successfully completed the Tunnel de Bure on October 15, 2008. It is the most northerly large-scale tunnel of a 84 kilometer long transport link, leading the new Swiss A16 highway "Transjurane" through the Jura Mountains. The Single Shield TBM with a diameter of 12.535 meters, which is one of the largest of its kind, excavated the 2,899 meter long tunnel through marl and limestone in only nine months. This excellent performance is mainly thanks to the competent construction site team which achieved weekly top performances of up to 140 meters working in single-shift operation. Congratulations to Marti AG Bauunternehmung and the entire construction site team for this great success.

BURE | SWITZERLAND

PROJECT DATA	CONTRACTOR
S-397 **Single Shield TBM** Diameter: 12,535mm Installed power: 2,800kW Tunnel length: 2,899m Geology: marl, limestone	Marti AG Bauunternehmung

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

www.herrenknecht.com

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Contents

FRONT COVER:
The 9.7m diameter Robbins main beam shield TBM breakthrough on the 2.4km long adit as part of the 15.4km long Ceneri Base Tunnel in Switzerland (p10)

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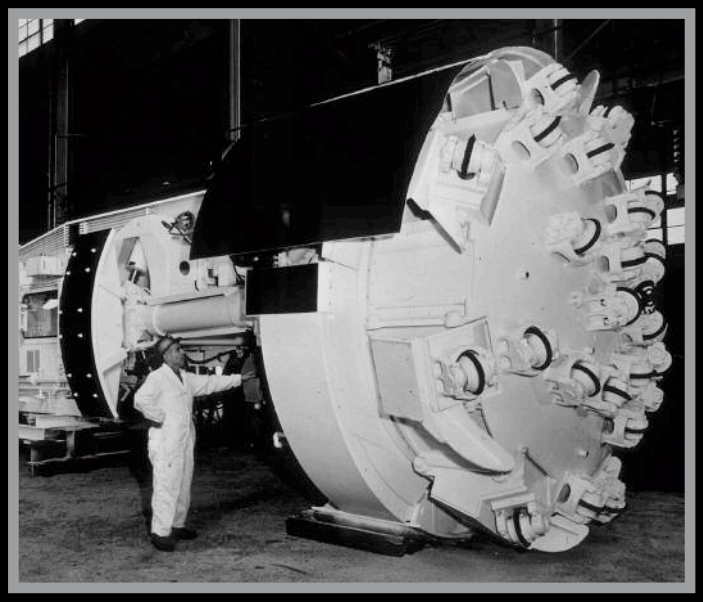
TBM FOCUS

16

One of the three 9.56m diameter EPBMs supplied by Mitsubishi for the Dubai Metro

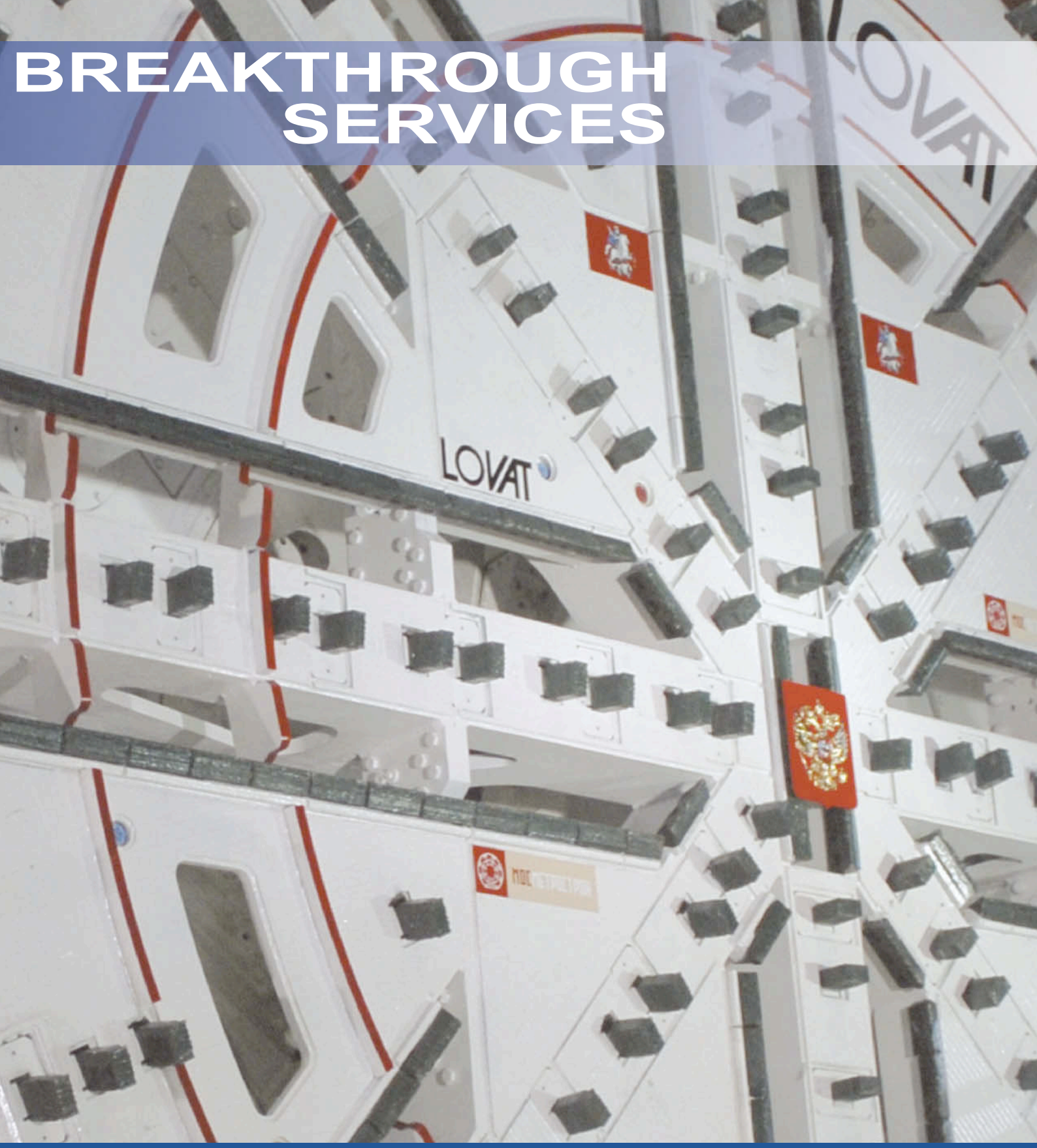


29

The Robbins TBM used in Melbourne, Australia was the first hard rock hybrid machine

PRE-CAST LINING

BREAKTHROUGH SERVICES



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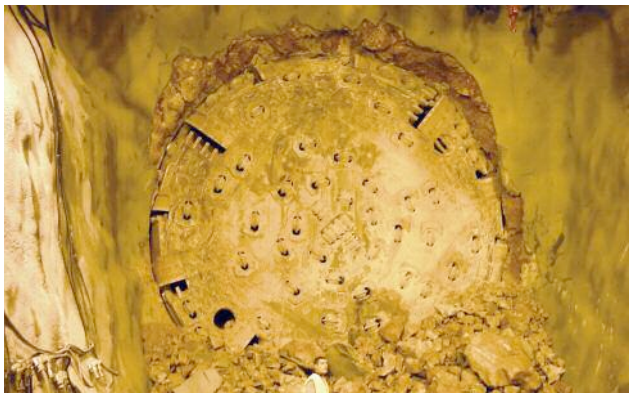
Round up...

It was another year of ups and downs for the tunnelling industry, a situation we must surely all be getting used too by now. Whilst the world recession, which started pretty much in mid 2008, is now in full swing, the heavy civil engineering fraternity appears to be coming away reasonably unscathed. Certainly by comparison to, say, the housebuilding industry, and positively glowing when compared to the retail industries. The UK's tunneller's will be happy with the upcoming Crossrail, Tideway and raft of cable tunnels, not to mention London Underground's planned refurbishment works. In the US, huge resources are being plowed into infrastructure, not least hopefully for California's High Speed Rail Network (see T&TNA comment) and the deluge of works on the cards for New York. Australia promises to be a hot spot for large scale tunnelling projects for the next five to ten years, whilst China rumbles on as the leading tunnel builder in the world in term of kms planned or being built. Singapore will once again rise as a place to be, with plans to relocate all infrastructure underground, and India, the once silent achiever now genuinely threatens China in terms of tunnels planned. There are plenty more examples of where the works will be picking up, but space limits us, and this needn't just be a list talking up possible future opportunities. If projects are the industry's payoff, then certain "issues" within the discipline can be seen as our own personal nemesis. We've banged on about this on many occasions, but here are just a couple of areas that at the very least need a bit of attention, if not a radical re-think. As an industry we must get back to the old days of the entrepreneurs who took their ideas and solutions to the decision makers and actually created their own destiny. Problems were solved before they were even known and finances were drummed up by the personal barracking of those who stood to benefit from the construction. This is how the civil engineers of the Victorian era earned their reputation as movers and shakers, a true celebrity of the time who made a real impact on peoples quality of life, as opposed to today's lame Big Brother contestant misfits desperate for their 15 minutes of fame with nothing to offer the world but fake tans and breast implants. Next we need to make the industry more attractive to the young. By becoming an actionary rather than reactionary industry, as displayed by the Victorians, we can hope to draw in the dynamic brains of the next generation, but mark my words, if they are not paid what they deserve, or given reasonable work/life balance they will go elsewhere. There are many more areas where we need to improve as an industry both technically and holistically, as you will know, being at the work face so to speak. It may be a good idea to spend some time putting our own house in order if we are to truly benefit from future opportunities in 2009 and beyond.

Tris Thomas

COMPANIES IN THIS ISSUE

Cabrera completed



Excavation of the twin tube, Cabrera high-speed rail tunnels, in Spain, have been completed ahead of schedule by the JV contractor using a 9.69m diameter Herrenknecht TBM.

The double shield completed the first, almost 6km long drive through sedimentary rock at the beginning of this year and was relaunched in May, ahead of schedule, on the second bore where it achieved a best day of 105.6m (66 rings) and best week of 435m (290 rings).

The average weekly and best month advances made by the shield (S-373) on the second drive were 284m (178 rings) and 1,688m (1,055 rings), respectively.

While the top daily rate on the second drive was much faster than the first, the best weekly and monthly performances were reasonably comparable. The construction time was a month shorter, at less than five months, on the second run. Herrenknecht said that sufficient progress was made to cut the construction period by a quarter.

On the first drive, the contractor – a JV of FCC Construccion and Construcciones Sanchez Dominguez-Sando – achieved comparable progress rates for best week and day of 430.4m (269 rings) and 83.2m (52 rings), respectively. Best month was 1,598m (1,000 rings).

The alignment through the Sierra de la Cabrera comprises limestone, dolomite geology and the TBM has cutterhead power of 4,900kW with 13 back-up gantries. The 8.75m i.d. rings are 1.6m long with seven segmental sections up to 8.8 tonnes, and the double shield enabled concurrent advance and lining work. The tunnels have been constructed with a 3% gradient.

Tunnelling on the project began in mid-2007 and with the plan earlier this year for relaunch to be underway about the end of the second quarter or shortly after, the programme anticipated final breakthrough this month (*T&TI*, March, p11). However, progress achieved on the second bore, drawing on the experience of the parallel first tube and the established equipment and logistical support enabled the TBM to hole through in late September.

The Cabrera running tunnels are linked by cross passages nominally every 400m, and each main bore is, in total, 7.25km long. The tunnels are being built by Spain's rail network company, ADIF, as part of the 11.2km section of the Siete Aguas-Bunol part of the high-speed link from Valencia to Madrid.

There are two other, shorter tunnels of the Siete Aguas-Bunol section of the high-speed rail link – the 1,856m long Bunol and 424m long Siete Aguas tunnels. In total, and with being by far Cabrera the longest, the three stretches of tunnel have a combined length of 9,527m. The entire link is to be operational by the end of 2010.

Milan gets busy on M5

Lovat's EPBM despatched to Italian subcontractor Ghella is advancing well in its drive to extend the Milan metro with construction of the twin-track line M5.

The 9.4m diameter mixed face shield is driving more than 3.5km through gravel, sands and some weak silts with cover of 8m-12m. The drive, in the north of the city, is mostly above the water table.

Fitted with ripper teeth and scrapers, the cutterhead has power and maximum torque of 2,700kW and 24,940kN at 1rpm, respectively. Tunnel segmental lining is 8.15m i.d., 350mm thick with rings 1.5m long.

Lovat delivered the refurbished shield (RME370SE Series 19601) and is providing Ghella with onsite service and spare parts support. Ghella is undertaking the tunnelling works under a subcontract to the main, joint venture contractor – Italian construction groups Astaldi and Torno Internazionale.

The M5 line will run north for 5.6km from Garibaldi main rail station to Bignami with intermediate stations at Isola, Zara, Marche, Istria, Ca'Granda, Bicocca and Ponale – from where the shield has already been relaunched on its southbound run after the first intermediate breakthrough.

At Garibaldi and Zara the M5 line will interchange with lines M2 and M3. The line is to come into operation in two stages: the Zara-Bignami section by March 2011; and, the final, 1.25km long Garibaldi-Zara section by May 2012. The line is forecast to carry 29M passengers annually.

The concession for the project was awarded to a consortium of Astaldi, Ansaldo, Torno, Alstom and ATM, for 32 years, including a five years construction phase. Design and construction of the line has a budget of approximately US$740M and, as Italy's first major urban transport with private finance it has been structured on a 60:40 debt to equity basis, the debt finance coming from the city, state and banks loans.

The new line with automatic, driverless trains is eventually to be extended to Monza, it is proposed, with four intermediate stations. There is also a proposal on the cards for a westward extension from Garibaldi to San Siro with nine intermediate stations.

Hangzhou metro pit collapse

Poor construction and safety management have been blamed by Chinese national authorities for last month's fatal collapse at the open cut tunnel excavation for a new metro station in Hangzhou, Zheijiang province.

Official figures put the death toll at 21 in the collapse caused by the failure of the reinforced concrete walls and steel pipe bracing. The collapse happened mid afternoon on 15 november, at the Xianghu station area on the southern end of the Line 1 project. Those killed were construction workers buried under mud that half filled much of the 16m deep excavation.

Traffic was running on the road skirting the west side of the pit when the ground dropped behind the failed wall, which split, kicked-in and tilted. The pit bracing failed, generally falling out of place, intact, and both walls moved and cracked, and saturated soil flowed into the excavation. However, the edge of one section of failed wall looked to have a long vertical, clean, brittle fracture through its depth and there was little sign of steel reinforcement.

Water from the nearby river also began to seep into the sodden ground and an elongated, flooded crater on the west side, resulting in flooding of some metres deep which worsened the slurry conditions and emergency pumping requirements. A string of at least 11 vehicles were stuck in the crater, but higher up a car fell into a large crack that opened up in the road. Following the collapse, nearby buildings had to be demolished on unstable or suspect ground. There were no casualties among the public and residents.

There were up to four hundred rescuers on site. Emergency services and workers had found the first bodies – four by the end of the next day, in mud – and they still tried, digging with shovels, to find if there were survivors among the 17 then missing, but later recovered as dead. Fifteen other workers who escaped, a number by hoist, were treated in hospital.

In total, the section of works affected by the collapse was 100m long by 50m wide, reported the State Administration of Work Safety (SAWS). The depth of the crater was given as 6m, though at the deepest point the road could be seen to have dropped more than the height of two lorries.

Following a preliminary investigation, SAWS outlined five main problems that it concluded had led to the fatal collapse. For the project parties, the failures range from poor construction management to insufficient technical and safety training, and non-standard employment of workers. The state body also criticised the local government for inadequate supervision of the construction works.

Following the accident, the Chinese authorities ordered immediate safety checks on all ongoing construction projects in the province and nationally, especially metros.

In Hangzhou, the Line 1 metro project is being developed by the city's mass transit rail authority. SAWS said the section involving works at Xianghu had the following parties involved: design was done by Beijing Urban Construction Design Research Institute; supervision was provided by the project consulting unit of Tongji University, in Shanghai; and, construction was being performed by China Railway Group's fourth engineering bureau, known as China Tiesiju Civil Engineering Group. China Railway Group was formerly China Railway Engineering Corp (CREC).

Local, unconfirmed reports say workers had allegedly noted cracking and subsidence movement in the adjacent road weeks before the collapse, and that there had been patch up and strengthening work. Reports also said a number of workers on the job were from rural areas and their training had been limited.

The works at Xianghu are part of Phase Two of the Line 1 metro development, most of which commenced in mid-2007, said the provincial government. Xianghu station is located on the south bank of the Qiantang river in Xiaoshan district, in the south east of Hangzhou. Out of the eight stations on Phase Two, the construction work on Xianghu started last due to design changes, noted the provincial government.

The other stations in the second phase are Binhelu, Xixing, Binkanglu, Zhanongkou, Genshanmen, Xiashaxi and Qichecheng.

The works for Phase One began in March 2007 and has involved a staggered construction schedule for six stations – Jiubao East, Binjiang, Wenze Road and three stations to be located underground in the Qianjiang New City area. Completely unrelated to the incident last month, a section of tunnels near Binjiang station is being bored by Shanghai Tunnel Engineering (*T&TI*, September 2007, p6).

With the first sections of Line 1 due to open before 2012, the entire length of the metro route will be 48km with almost 42km of the route to be built underground. The completed line is to have 30 stations. Early concept and feasibility studies for Line 1 were undertaken by MTR Corp, of Hong Kong, and Parsons Brinckerhoff. The preliminary design was approved about two years ago.

Preparing for boring at La Confluencia

Early site work focused on rock stabilisation for the La Confluencia hydropower project, in Chile, is about to give way to the commencement of underground activities with the arrival of the first jumbos.

Sandvik is supplying the joint venture contractor Hochtief-Tesca with six DT 720C jumbos for the tunnelling works. For the rock preparatory works, the company also supplied three DC300 surface drill rigs, and the contractor has also used an Atlas Copco XAS 186 portable compressor to support the shotcreting.

The La Confluencia project is being developed 150km south of the capital, Santiago, by a joint venture of Australia's Pacific Hydro and Norway's SN Power, together operating as Tinguiririca Energia. The developer has a budget for the scheme of approximately US$350M and awarded the US$220M turnkey contract to Hochtief-Tesca a year ago.

La Confluencia is being built in the Tinguiririca valley and is to be commissioned in 2010. It is located upstream of the La Higuera project, being developed separately by the Pacific Hydro-SN Power JV.

In the valley, the project involves almost 20km of tunnel construction arranged in two low-pressure conveyance tunnels to supply water from the Tinguiririca and Portillo rivers. The lengths of the tunnels are 11km and 9.3km, respectively. The tunnels will terminate in drop shafts leading to a high-pressure tunnel supplying the surface powerhouse. Excavation also includes construction of a surge chamber.

Tunnelling will involve up to 10 active fronts in the branch tunnels. The contractor added that the programme advance rate is 9m per 24 hours from two full cycles, but noted that it has not been possible to predict with certainty the rock conditions along the alignment.

The jumbos are to be fitted with 45mm diameter, Sandvik R32 drill tools with nine-button RT300 bits. The jumbos will be followed by the DC300 rigs for reinforcement drilling, and will be fitted with a 51mm diameter and 38mm diameter R32 tools for the central and surrounding holes, respectively. Following the installation of reinforcement, the tunnels will be lined with shotcrete.

Site preparation for the underground works at La Confluencia, Chile

Leighton grabs HK sewer contract

Preparations for excavation work on the Lai Chi Kok sewer project are underway following Leighton Asia being awarded the construction contract by Hong Kong's Drainage Services Dept.

The transfer project involves design and construction of two stormwater tunnels, six intake shafts, a stilling basin and an outfall structure. The tunnels have a total length of 3.7km, a finished diameter of 4.9m and will be excavated at depths up to 80m. The project also involves construction of approximately 270m of 3m i.d. connecting adits.

The contract was awarded last month and has a value of almost US$173M. Leighton Asia is part of Australia's Leighton group, which is owned by Germany's Hochtief.

Stormwater drainage improvements will be gained in the areas of Lai Chi Kok, Cheung Sha Wan and Sham Shui Po following successful completion of the project in 2012.

The Lai Chi Kok section will see upstream flows intercepted at the West Kowloon hinterland and potential overflow from the Kowloon group of reservoirs, which will mean road excavation is minimised in the lower areas. The flow will be conveyed to Victoria Harbour for discharge near Stonecutters island.

The project is one of many major sewer projects that the either underway or in planning in Hong Kong. Prequalified contractors are being invited shortly to bid for the two tunnel contracts – DC/2007/23 and DC/2007/24 – of the Harbour Area Treatment (HAT) scheme, which involves a total of 19.5km of sewer with excavated spans of 4m-5.5m (*T&TI*, September, p13).

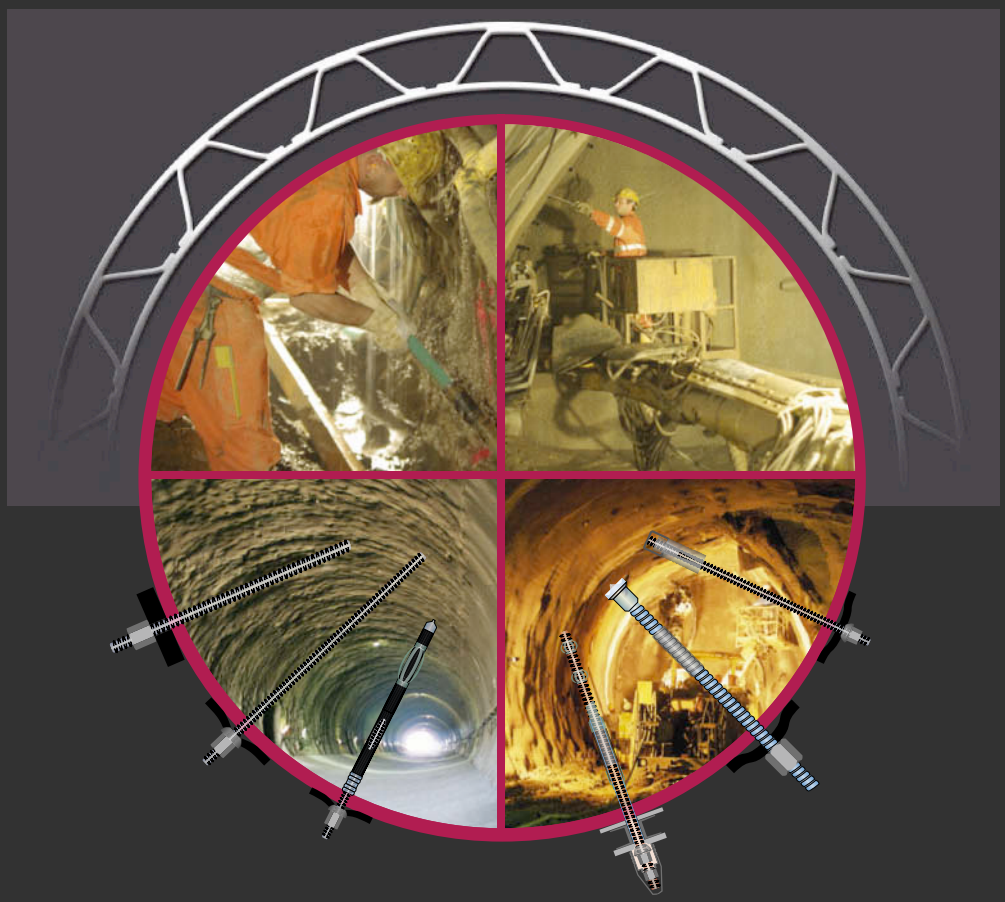
Chunnel shotcrete repairs speed to early Jan finish

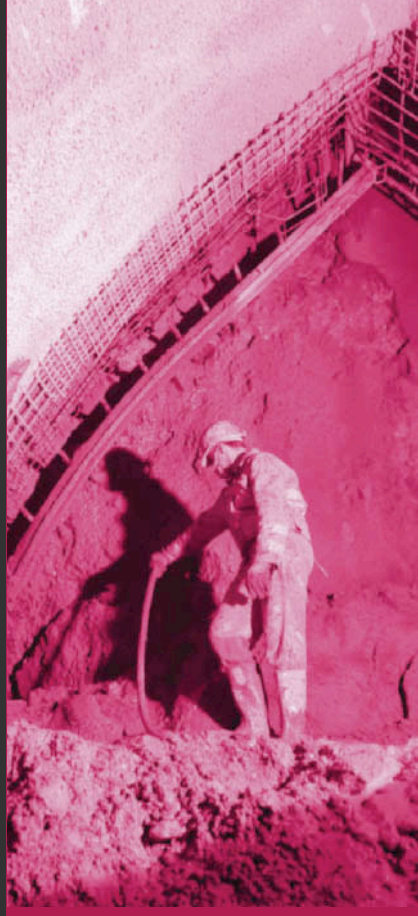
Shotcrete repairs to the fire-damaged segmental concrete lining in the northbound running tube of the Channel Tunnel, nearest the French coast, are expected to be completed by early January, slightly ahead of programme.

The worst damage in "Interval 6" is over a 550m long section out of 650m to be repaired, and shotcreting is advancing more than 20m/day. Following hydrodemolition work on the damaged lining, the shotcreting began early this month.

Working from a long scaffold system, contractor Freyssinet is tackling multiple faces. Work is being supervised by SETEC (*T&TI*, October, p7). Following the structural repairs the client, Eurotunnel, aims to have the new track, cabling and catenary installed and the tunnel back in service by mid-February. The repairs are to cost less than US$76M.

GROUND CONTROL SOLUTIONS





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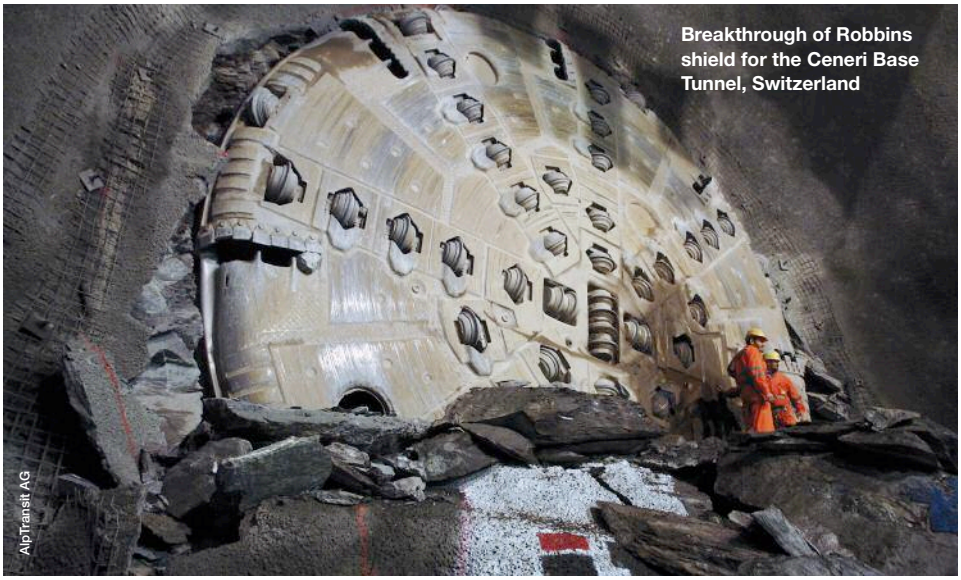
Gotthard, Ceneri wins

The anticipated difficult syncline geology of the Piora Basin has been safely crossed by the first of two Herrenknecht TBMs on the Faido section of the Gotthard Base Tunnel, in Switzerland, which has less than 20% of excavation work left to be completed.

Separately, excavation of the access adit for client AlpTransit's associated Ceneri Base Tunnel project was finished in early November at Sigirino, paving the way for the main tunnelling works.

The Gotthard project centres on twin, 57km long rail tubes. By the beginning of this month, excavation at Gotthard was 80.2% complete, equating to 120.5km from the total of 153.3km of the tunnels, galleries and passages to be bored. Last month, a total of 2.4km was excavated on the project.



Breakthrough of Robbins shield for the Ceneri Base Tunnel, Switzerland

On the Faido section, which is more than 14km long, a pair of 9.43m diameter Gripper TBMs (S-210, S-211) were launched in July and September last year. The contractor – a JV of Implenia, CSC, Impregilo, Hochtief and Alpine – had previously used the shield on the Bodio section. On the Faido stretch the most difficult ground was anticipated to be at the faulted Piora Basin about halfway along.

Geologists had debated about the construction risks related to the grainy dolomite and high water pressures in the 150m wide Basin, which were found by a 5.5km long exploratory adit driven by TBM in 1996. Water pressure of 150 Bar was met and within three hours the 100mm wide drill hole had discharged 1,400m^3 of slurry. The shield was recovered and the adit closed with a 8m thick concrete plug.

The exploratory adit was excavated 350m about the level of the Faido running tunnels Subsequent probe drillings and the recent face drilling in the east tunnel, ahead of the S-210 shield, confirmed the dolomite rock to be hard, non-aquiferous and suitable for mechanised excavation.

Herrenknecht said the approach to the Basin involved major modifications to reduce the risk of downtime and the regular maintenance shift was dropped during the passage to minimise the problem of rock squeezing. The tunnel lining involved ribs at 1m centres directly behind the cutterhead, shotcrete to seal the face and then a 300mm thick layer of further shotcrete applied. Despite the risks identified during investigations, the TBM cleared the basin without problems.

The sister shield, S-211, driving the west tunnel is due to enter the Piora Basin stretch in the first quarter of 2009.

Separately, at Ceneri, the 9.7m diameter Robbins TBM last month completed the 2.4km long adit, which intersected an exploratory tunnel. The intersection already has the installation caverns that are the mid-route launch area for the two main running tunnel bores, each of which will be 15.4km long and excavated by both drill and blast, and TBM (*T&TI*, March, p10).

The Robbins TBM, launched in February, is a refurbished main beam shield that was previously used on the Karahnjukar hydropower project, in Iceland. It was increased in diameter from 9.6m and fitted with 19" for the JV contractor, including CSC, Lugano, Frutiger, Thun, Rothpletz, Lienhard+Cie, and Aarau. Geology along the adit alignment comprises schist, molasses and orthogneiss of UCS 30MPa-130MPa.

Mavi move in Turkey

Excavation is due to commence this month on the Mavi ("Blue") tunnel project in Turkey using the double shield, back-up and equipment supplied by Seli.

The 4.88m diameter TBM is to bore a 17,061m length of the water transfer tunnel for contractor Ilci Construction. The US$11.4M contract was awarded in October 2007.

Geology along the alignment comprises limestone and sandstone.

Fitted with 17" cutterhead discs, the shield has been designed with a maximum thrust of 8,544kN and drive power of 1,890kW (6 x 315kW). The cutterhead speed is up to 10.9rpm.

The TBM-driven section of tunnel will be lined with hexagonal precast concrete, each 1.3m long ring consisting of four segments of 250mm thickness. Seli has supplied the segment moulds as well as other equipment.

In addition, to deliver the complete equipment package for the contract, the manufacturer has also supplied the spoil removal transport. The trains have been designed to enable the TBM to advance by 4m per hour - or approximately three rings - at the maximum distance of the machine from the portal.

Seli said that the TBM section of the Mavi tunnel is scheduled for completion around the end of 2010. Tunnel construction includes a further stretch of 995m by conventional excavation.

Seli TBM for driving the Mavi tunnel, part of Turkey's Bagbasi water scheme

The tunnel is part of the Bagbasi water resources scheme, in Hadim district of Konya province, and is being developed by the Directorate of the State Water Works. Groundbreaking on the scheme was mid-2007.

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Further progress for Crossrail

Key steps were achieved last month in the future leadership and support for the Crossrail tunnelling project in London as well as its funding and procurement.

The project is to be headed by Tube Lines' chief executive Terry Morgan as non-executive chair from November 2009. Tube Lines has a public-private partnership (PPP) contract with Transport for London (TfL) to upgrade the following deep metro lines in the capital – Jubilee, Northern and Piccadilly. He was previously group managing director for operations with BAE Systems.

The responsibilities of the executive chairman role, held by Douglas Oakervee, are being split between the new non-executive chairman post and also the chief executive position, for which recruitment is also underway. He will keep the responsibilities that will be assigned to the non-exec chair role until Morgan joins next year.

Crossrail also proved to be a jewel in the crown in the truncated transport infrastructure plan for the next decade that was announced last month by TfL and the Mayor of London. While some other projects were deferred, the strategic importance of Crossrail to the capital's future economic growth kept support for the scheme.

Crossrail is being built by Cross London Rail Links (CLRL), and will involve excavation of 41.5km of 6m i.d. twin tube tunnel using seven TBMs, starting in 2011. Enabling works start next year.

CLRL has also announced the shortlist of three parties for the Programme Partner contract, dropping Mouchel and keeping Bechtel and two JVs: Legacy 3 (Parsons Brinckerhoff, Balfour Beatty Management and Davis Langdon); and, Transcend (Aecom, CH2M Hill United Kingdom Unlimited and Nichols Group).

Funding for Crossrail also took a further positive step forward last month with the agreement of airport operator BAA to contribute US$344M in outturn prices toward the cost of constructing the scheme, which will run through the heart of the capital and link with Heathrow airport. Adjusted for inflation to early 2007 levels, the contribution - which is subject to regulatory approval – is £180M.

BAA owns and runs the airport, and CLRL has guaranteed that, in return for the funding, the company will receive a fast train service to run four times per hour for much of the day. The airport operator already runs an express link from Paddington station, which Crossrail will also pass through, and said the services would be complementary. BAA will give the funds in two tranches via its subsidiary Heathrow Airport Ltd.

The US$23.8bn scheme has Government fundings and contributions from businesses set to benefit from the transport scheme due to start operations in 2017. Approval of the project was given in July (*T&TI*, September, p7).

Five parties have been shortlisted to bid for the project delivery partner contract: Bechtel; Laing O'Rourke Holdings; Legacy 3; Capita Symonds with NNN; and, Fluor, Ove Arup and EC Harris (called Flare).

There were 15 parties invited to tender for the design framework contracts.

For the construction phase of the tunnelling scheme, CLRL plans to use Optimised Contractor Involvement (OCI) to take forward the procurement process.

Call to BTS Young Members

The Young Members' Committee of the British Tunnelling Society (BTS) has issued a recruitment call to clients and contractors as momentum builds for the recently launched group.

Last month, the Committee was invited to the Thames Tunnel Banquet at the Brunel Museum, in south east London, which saw the reopening of the Grand Entrance Hall after 140 years. It plans to work on public and young peoples' education with the museum, and noted that Isambard Kingdom Brunel was a youthful engineer working with his father, Marc, when the tunnel was built.

The Committee's second full meeting is this month, led by its founder, Kate Cooksey, who has also been shortlisted as a Graduate of the Year by *New Civil Engineer*, notes her employer Morgan Est. Her contact with the firm began during a sandwich degree and MEng in civil engineering at Cardiff University. She has worked on the London Ring Main extension from Brixton to Honor Oak, and led a flood defence project in Ormskirk, near Liverpool.

The Committee will be working to support the activities of the BTS main committee, and aims to boost the profile of the tunnelling sector among young engineers. A number of social events are also planned for the coming months.

Debate begins over new Brisbane bores

A proposal has been put forward by the Royal Automobile Club Queensland (RACQ) for a change in tunnel plans that would see Brisbane City Council's "Northern Link" road project scrapped in favour of its alternative "North West Bypass" plan, submitted last month to the Australian Government.

Both proponents have developed concepts that tackle the transport problems of linking the west side of Brisbane to the north and the airport. While the debate has taken off, work is underway on two separate projects that will form a north-south axis through the heart of Brisbane and link to the airport, in the northeast sector.

RACQ is calling for its North West Motorway option as the scheme would deliver a full bypass and ring road package for the west of the city. However, while not having costed the scheme, nor detailed the substantial tunnelling involved, RACQ estimates than the budget should be approximately US$6.4bn.

The organisation's proposal emerged from a recent study – Western Brisbane Network Investigation – by the Queensland Government. RACQ said that a number of potential projects were identified and it has made a strategic selection that would establish a unified scheme. It added that no other bypass scheme would be required for the west of the city in the long term.

RACQ has called on the Government's transport arm, Infrastructure Australia, to commission a feasibility study into its proposed alternative to the Northern Link.

Brisbane City Council's proposal for the Northern Link envisages a 6.4km long route of which two-thirds would be built in tunnel. The underground section would be constructed as two-lane twin tubes with cross passages every 120m. A variety of excavation methods would be employed on the project, which is at the Environmental Impact Study (EIS) stage.

Separately, RACQ also called on the Government to fund construction of the Toowoomba Bypass, which would be a four-lane twin road and 735m long tunnel project with an estimated cost of US$1.28bn. With the completion of the 600m pilot tunnel, RACQ wants the Government to fund construction.

Elsewhere in Brisbane, on the north section of the "north-south" axis projects, BrisConnections has just formally started construction of the Airport Link and Northern Busway scheme. The contractor is a JV of Thiess and John Holland. The scheme involves a 5.7km long stretch of twin bore tunnels, and both roadheader and TBM excavation is planned. Two TBMs are on order with Herrenknecht.

Immediately south is the North-South Bypass, much of which is in tunnel is under construction by roaders and twin Herrenknecht TBMs. The concessionaire is RiverCity Motorway Group and the JV contractor is Leighton and Baulderstone Hornibrook with support from Bilfinger Berger (*T&TI*, July, p25-27).

Also, recently, the roadheader excavation holed through for the Boggo Road busway tunnel.

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London's VSU project moves closer

Preparations for the tunnelling works on the Victoria Station Upgrade (VSU) project for the London tube network to relieve peak time congestion are moving ahead - the public enquiry has entered its final stages and this month is the deadline for tenders to be submitted for the main works contract.

The public enquiry for the VSU project began on schedule in late October and is expected to last approximately two months. The shortlisted parties were invited in September to bid by December for the main works contract.

Subject to the outcome of the public enquiry, the client London Underground (LU) hopes to award the contract next year. The job will be awarded under the NEC form of contract, on a target cost basis.

The entire project, including preparatory works, is budgeted at just under US$1bn (in Q2-'07 currencies). The initial OJEU notice for the works, issued in January 2008, indicated a price range of US$685M-US$783M.

The project calls for the construction of a number of new passenger access tunnels, a new ticket hall and an enlarged ticket hall. Most of the tunnels will be approximately 6m high by 5.5m wide, and the largest bore on the project will be 9.3m high by 10m wide for the 30m long escalator barrel at the enlarged ticket hall.

The new passenger tunnels will be run over the main station tunnel due to restrictions in alignment in the local area. They will require both significant sprayed concrete lining (SCL) works, it is envisaged, as well as jet grouting. Most of the excavation will be above London Clay, in the waterbearing River Terrace Deposits.

The lead consultant for VSU is Mott MacDonald. LU and Motts have noted that such a construction method in the wet ground, and its scale, would be more like that undertaken in Continental Europe, such as at Cologne metro. However, the use of SGI rings has not been ruled out and would depend on contractor proposals (*T&TI*, June, p16-19).

Constructibility of the tunnel has been checked by the design team with support from London Bridge Associates and Gall Zeidler Consultants.

The ticket halls are to be constructed as open boxes. The new North Ticket Hall will be 75m by 30m and 10m deep, constructed in two phases. The enlarged section of the South Ticket Hall will be 30m by 40m and approximately 8m deep.

Normet in Latin expansion

Normet has acquired Chile-based tunnelling and mining equipment manufacturer Semmco in an strategic move to expand into Latin America.

The Finnish group said both companies had key expertise in sprayed concrete and pointed to Semmco's development of a robotic wet process as important. The Chilean acquisition also manufactures concrete pumps and equipment.

The Semmco business and activities are to be merged with Normet Chile, which will locate in Semmco's facilities in Santiago. All 45 staff are transferring under the deal. The business will operate under Normet Americas.

Normet's chief operating officer, Tom Melbye, who noted he has known the Semmco family owners for 15 years – as both competitors and partners - said: 'This acquisition brings a whole new dimension into Normet.'

Semmco's revenues for this year are estimated to be US$7.6M.

A year ago, Normet announced plans to pursue both acquisitions and organic growth in its plan to be a global player in speciality underground equipment.

It also saw a strategic shift from being product-driven to market-driven with an expansion in customer service capability.

Another increase in Herrenknecht trainees

Herrenknecht increased its annual intake of apprenticeship trainees in 2008 following the step up in training activity in the previous year.

The German TBM manufacturer took on 65 trainees in the third quarter of the year to undertake either apprenticeships or its cooperative education programme.

Last year, Herrenknecht took on 57 trainees, a major increase over the 2006 level of 34. It said the 10% rise in intake numbers over last time was greater than the industry average. Inside two years, its annual intake rate of trainees has almost doubled.

Currently, it has 178 young trainees, which is an increase of approximately a third over 2007. Early next year, it will open new premises for trainees.

Of the total number under training, two-thirds are in industrial activities while the remainder are in commercial and technical activities. There are 20 high school graduates in the co-operative education programme.

Berger sells Razel to Fayat

Weaker markets in France had prompted Bilfinger Berger to sell its French subsidiary Razel, active in tunnelling and earthworks, to construction group Fayat.

The sale to the French group is subject to regulatory approval. Berger said that this year Razel should generate output volume of approximately US$637M. Fayat said the move would help it strengthen its position in the public works construction market.

Razel is mainly active in France, where it has worked on tunnelling projects such as metros in Toulouse and Rennes, the 5.4km long TGV tunnel in Marseilles and various road projects. It is also active more widely in civil engineering and geographically in Europe as well as francophone Africa, and has been part of the Berger group for 13 years.

Berger added that the divestment is expected to generate proceeds of US$175M and deliver a capital gain of US$115M.

At group level, Berger is establishing a risk provision to reflect construction market volatility going forward. However, it said that for the current year its net earnings should reach approximately US$236M, which is a third more than in previous forecast.

Changes at Arcadis, Häny and DSI

Changes have taken place in leadership roles in Arcadis, Häny and Dywidag-Systems International (DSI).

At Arcadis, ITA board member Yann Leblais will take on the new post of global director for infrastructure from next month. The consultant plans to pursue commissions for large, more complex infrastructure projects.

Grouting system manufacturer Häny has appointed Bernhard Korfitsen to head up its Mixing & Injection Technology division, also from next month. He takes over from Reinhard Muller, who led the division for 35 years. Korfitsen has been with the company for a year, having worked previously as a project manager.

At DSI, key recent appointments were Alan Bate as group chief executive. Bate has taken over from Howard Poulson, the chairman and acting chief executive. He was previously a vice president with ICI and led the adhesives and electronic materials business. The business unit was sold to Henkel group by Akzo Nobel, which bought ICI.

DSI also appointed Paul Taaffe as chief financial officer. He was previously with private equity-owned automotive group Aksys.

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The Dubai Metro Tunnels

Dubai's metro scheme was presented to the October BTS meeting by Paul Groves, Atkins, Junichiro Nakayama, project manager bored tunnels JTM JV, and Vijay Singh, tunnels resident engineer for Systra/Parsons JV and covered the Red and Green Lines construction

The Client for all works is the Dubai Roads & Transport authority (RTA) for which two lines of the metro system are currently under construction totalling some 70km route length, of which 13km will be in tunnel, beneath central Dubai and the Dubai Creek.

The 52.1km long Red Line will have 29 stations, four of which will be underground. It will run from Rashidiva to Jebel Ali, on a north/south axis through the main thoroughfares of Dubai. The 17.6km long Green Line will have 14 stations of which six will be underground, and will have two interchange stations with the Red Line at Burjuman and Union Square.

Plans are already in place to extend the network by four new lines, a Purple Line (49km), a Blue Line (50km) and Palm Deira Yellow and Black Lines (26.5km), with extensions to the majority of lines planned.

Detailed design

This section on the detailed design was presented by Paul Groves, Atkins Tunnels Design Package Manager, who explained that Atkins was appointed as detailed designer by the design and construct civil contractor, JTM JV, the civil partner in the single contracting organisation DURL CONSORTIUM. The rail systems partner was Mitsubishi Corporation. The Engineer to the Contract was Systra/Parsons JV.

The Design & Construct Contract document contained a Reference Design (DCP1) produced by Systra and this had been developed by Atkins through the following project detailed design stages:

- DCP2: Preliminary design
- DCP3: Detailed design (fit to commence construction)
- DCP4: Fully Approved Design

The detailed designer also had a continuing involvement during the construction phase in a support role.

Investigations were developed from Pre-Tender Site Investigation (SI) data by way of a geological desk study. Further SI for the detailed design comprised boreholes, in-situ tests within boreholes, lab testing, pumping trials and geophysical and bathymetrical surveys. During construction, further boreholes, trials and tests, foundation inspections and mapping of exposures were carried out.

Ground comprised loose to medium dense, high permeability marine sand, cemented sand Sabkha deposits with some hard concretions and voids, underlain by calcareous sandstone interbedded with cemented or uncemented sands (hence more of a soil than a rock material), underlain by interbedded gypsiferous sandstone and then siltstone. A high water table existed throughout the scheme, with the groundwater being hyper-saline (<1.08T/m^3). Both the ground and the groundwater were described as extremely aggressive.

Longitudinal sections of both the Red and Green Line tunnels are shown in Figure 1. Escape shafts are located as off line annexes at low points, combining sump pump discharge with ventilation and escape functions. A cross section of the 8.5m i.d. twin track tunnel is shown in Figure 2. The 400mm thick tapered rings were 1.5m long, each comprising seven segments plus a key. Segment accessories comprised 25mm spear bolts, EPDM gaskets & hydrophilic strips, cast-in threaded inserts and lifting eyes/grouting valves. A linear heat detector will be installed in the crown along the full length of the completed tunnels.

The structural design of the segmental lining was to BS 8110 and included for ground, water and surcharge loads, a seismic loading (0.15g), jacking loads from propulsion rams, and effects of ring building, grouting and handling.

The lining was fire rated to four hours (BS 8110) in fulfilment of the Contract. In order to provide the 100-year design life durability, the concrete mix used in all segmental linings was a blended C50 concrete mix, designed for a maximum crack width of 0.2mm, with 50mm cover to rebar on the extrados.

A flexible epoxy coating was applied to external surfaces.

Below: **Fig 1 - Longitudinal section of Dubai's Red and Green Line tunnels**

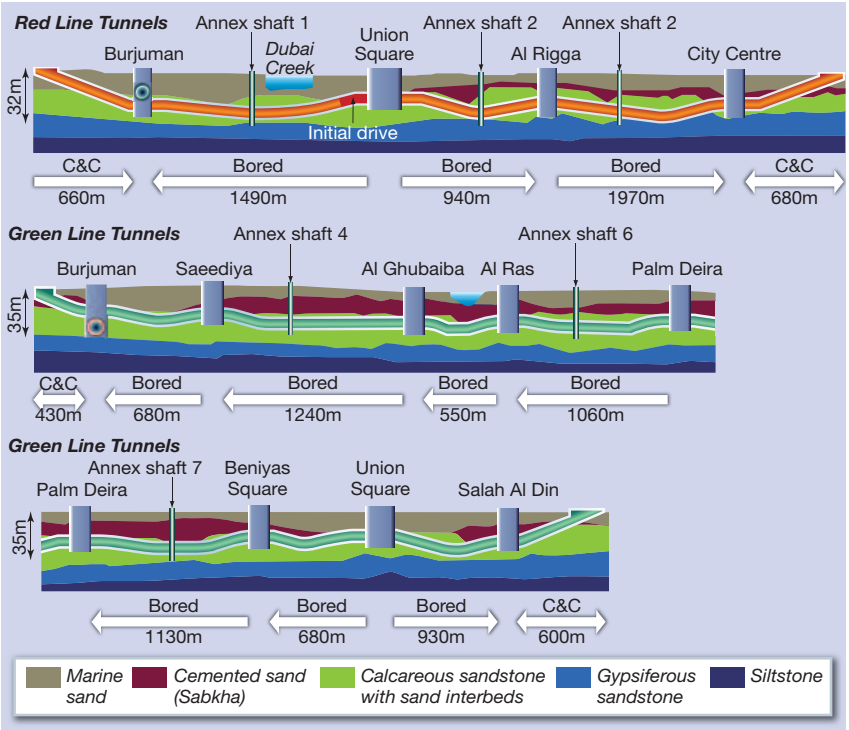


Table 1: Typical engineering properties

	Thickness (m)	Strength c' (kPa)	Strength ϕ'	Stiffness (E' MPa)	Permeability (m/sec)
Marine Deposit	5 to 15m	0	28 to 32°	15 to 30	$1x10^{-4}$
Cemented Sand (Sabkha)	5 to 12m	0.0512	32.0°	0.0530	$1x10^{-4}$
Calcareous Sandstone	12 to 18m	0.0632	18.0°	0.0707	$1x10^{-6}$
Gypsiferous Sandstone	2 to 12m	0.0632	18.0°	0.0707	$5x10^{-6}$
Siltstone	N.P.	0.0493	34.0°	0.0514	$1x10^{-7}$

Above: **A finished section of the metro tunnel**

Structural damage risk mitigation

Buildings & structures were described as typically low-rise or less than eight storeys, and were mostly RC framed structures on rafts or shallow footings. There were however some piled structures including some structures under construction, such as the deep basement Al Ghurair Centre, piled to below tunnel horizon.

The DNATA Building (Emirates Airline Centre) was described as being at greatest risk. This was a significant piled frame structure directly over the tunnel. The pile length was unknown, therefore an investigation of pile length was carried out by seismic logging and magnetic logging. It was found that pile toes were some 5m above the tunnel. The design approach adopted was to evaluate tunnel-pile interaction analysis to determine tolerable volume loss, from which it was found to be below 0.5%. It was considered preferable to achieve this using TBM operational pressures rather than intrusive mitigation.

The project adopted a risk based approach to structure damage risk mitigation. A risk assessment was conducted for all structures based on a volume loss of 1%, using the method postulated by Mair et al (1996). All piled structures were analysed using finite element methods. Additional measures were planned for structures considered to be at "slight or greater" risk. Back-analysis of monitoring field data from the initial Red Line drive was used to inform the process, with the result that the additional measures in terms of close monitoring and precise adjustments of face pressure and annulus grout pressure were sufficient controls and no further actions at the surface proved necessary. Such special measures were envisaged to be beneath the DNATA building on the Red Line only and not on the Green Line.

The project Environmental Impact Assessment identified two petrol stations at risk from settlement damage. The alignment passed directly under the storage tanks of one petrol station and passed close to another. Monitoring of ground water and of excavated fill was undertaken to check for tank leakage as the TBM passed, ensuring compliance with NFPA requirements.

TBM selection

With the intention of limiting settlement, the calculated face pressure was based on limit equilibrium of the soil wedge, with assumptions on chamber pressure based on Anagnostou & Kovari (1996). The annulus grout pressure was based on an analytical stability calculation for cohesionless soils, according to Atkinson & Potts (1977). Because there was no precedent experience of TBM tunnelling in Dubai, a trial initial drive was deemed important for validation. As a risk mitigation measure, a second screw conveyor was added to the back up, to ensure maintenance of face pressures in the cohesionless soils. Results from the initial and heavily instrumented Red Line trial drive were presented. Typical volume losses were around 0.3% with a maximum of 0.65% which correlated with some localised tailskin grout losses that was subsequently repaired.

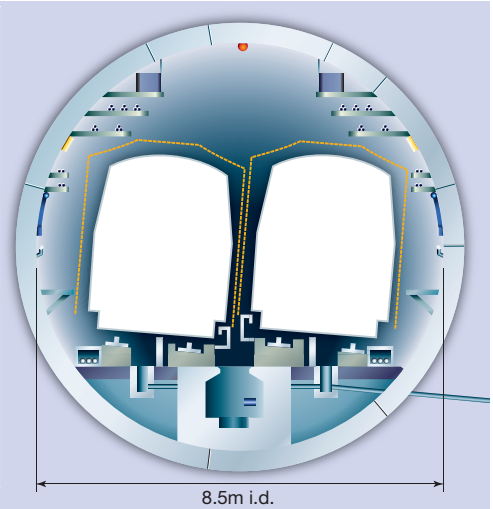
The Dubai ground conditions (much of which is cohesionless with a high percentage particle size around 0.1mm) were described as suitable for either an EPBM or Slurry Machine (STM). Japanese project experience between 1997 and 2006 of 322 STM projects and 932 EPBM projects was investigated by JTM.

It was decided that EPBMs would be used, with spoil conditioning using rheological foam injected at the face. This reduced the slump of the spoil sufficiently for a pressure gradient to be maintained along the screw conveyor and for the resultant spoil to be handled by conveyor and placed in a muckpile. Three 9.56m diameter Mitsubishi EPBMs were deployed on the project in ten separate drives. Four of the drives radiated out from Union Square, while two further drives on the Green Line 'loop' were driven from Palm Deira and Al Ras.

Below: **One of the three 9.56m diameter Mitsubishi EPBMs**

Table 2: TBM considerations

	STM	EPBM
Face stability	Slurry pressure risk of slurry leakage	Muck with foam screw conveyor x 2
Surface	Slurry treatment plant	Muckpile management
Muck discharge	Pipe line with slurry pumps	Muck cars, or belt conveyor



Above: **Fig 2 - Cross section of the lined 8.8m i.d. running tunnel**

The cutter heads were fitted with shell and scraper cutter tools projecting from the cutter head at two heights, with scraper bit shell bits at 145mm and shell bits at 105mm. Cutter tools were reported to be in good condition after the drives, thought to be a result of the sandstones not containing appreciable quartz cementation and in conjunction with the use of foam injection, did not prove to be particularly abrasive.

Muck removal was by conveyor with vertical conveyors in drive shafts. A combination of horizontal and vertical conveyor cassettes (one each in the tunnel and the shaft) gave a capacity of 200m without interrupting the drive. Average progress was 10 Rings (15m/day) with the maximum production in any 24 hour period being 21 Rings (31.5m).

Extensive data management systems were used, and the three TBM drive sites were connected to a common data system through the Internet. Real time monitoring, relayed to the surface site office included drive data, muck sensor control PC (linked with belt weigher), face & grout pressures, gas detection, camera images and total station data. The TBM data collection system was updated every minute.

Building settlement monitoring data was emailed to site offices, supplemented by automatically generated SMS messages to engineers' mobile phones if alarm values were triggered.

TBM launching

TBMs were launched from steel thrust frames through soft eyes in the station box diaphragm walls, initially with the aid of pre launch ground treatment. Sealing arrangements included launching eye, comprising a rubber seal with sprung steel plates. Leakage was negligible and it was subsequently decided to launch the other drives without further ground treatment.

TBM arrival at the end of each drive was though a partially dewatered zone created by a slurry wall parallel to and offset some 10m from the station box headwall, with pumping wells in the 'protected' zone.

The drive sequences were such that TBMs needed to be dragged/walked through four stations on steel rails cast into the base slab concrete – the fourth was ongoing at the time of the talk.

All grouting was through ports at the rear of the tailskin with a 2 component system, Part A comprising a cement bentonite grout, and Part B being sodium silicate. This mix set to a gel some 20 seconds after injection mixing. A dry tunnel was achieved through a good ring build and the presence of this primary grouting, and no further grouting through the lining proved necessary.

A casting yard was set up for the project, casting in high ambient temperatures well over 40°C, for many months each year. Two mix designs were used according to temperature and included silica fume.

Two production lines had been established, casting around 12 x 1.5m long rings (96 segments) per day. However, an early start to the Green Line had required a third production line, increasing output to 128 segments per day. Segment casting was due to finish in November 2008.

Safety & environmental

Accidents are reportable where the worker is off work for three days or more, not including the accident day. The target for the Metro was set at no more than 1 reportable accident per million man-hours worked. Approximately 113 million man-hours had been worked on the project, for which there had been 133 reportable accidents. The accident frequency rate (AFR) was stated to be 1.18. T&T

QUESTIONS & ANSWERS

Q: Mike McConnell (retired) noted that fire evacuation route for rail passengers was along a 0.61m wide raised walkway at about vehicle floor level, with evacuation shafts at 1.6km centres. He asked how long the evacuation of a train load of passengers was expected to take.

A: Paul Groves replied that maximum escape length from the train to a point of safety, either station or escape shaft, was 800m. Evacuation of a train load of passengers to a point of safety was estimated to take up to 24 minutes. He also noted that in his view, and probably that of most British tunnel engineers, train evacuation in a twin track tunnel was harder to achieve than in a single track tunnel arrangement. Nevertheless, the design has been developed to comply with the contract specifications and NFPA-130/ITI-98300 and was based on the contract reference design, produced by Systra and based on established French practice, which included the minimum tunnel diameter, twin railway tracks and elevated walkways.

Q: Gerard Skalla (Dr Sauer Company) commented that a grouted solution had been originally planned for ground stabilisation and treatment for breakouts.

A: Initial results of permeation grouting with silicates had proved that the grout was not giving the expected strength gain/permeability reduction, possibly because of the inherent salinity of the marine based deposits. Therefore, as a matter of expediency, slurry cut-off walls and deep pumping had generally been chosen instead.

Q: Andy Fletcher (Crossrail) enquired about community relations and, in particular, the complexities of obtaining the necessary approvals from the authorities and land purchase.

A: Paul Groves explained that the status quo in Dubai was such that due process for project authorisation was generally more straightforward than in other countries.

Q: Bob Goodfellow (Black & Veatch Ltd) asked about the numbers and locations of rail crossovers.

A: Paul Groves explained that there was a Red to Green Line crossover within Union Square Station and several track crossovers inside the tunnels, but since all running tunnels were twin track, no change in lining geometry was required for track crossings, which could therefore be located on straight tunnel sections wherever required.

Q: Martin Knights, ITA President, (Jacobs Engineering) asked a three part question regarding the cost of the project, the decision not to use fibre reinforcement in tunnel linings, and whether the participating companies were in a full joint venture.

A: Answering the first of these, Nakayama san explained that the project was unfinished, so the outturn cost was not yet known.

The second and thirds points were answered by Paul Groves who explained that steel bar reinforcement had been the contractor's preference and that the tunnel constructor JTM was a full joint venture.

Rapporteur: John Scholey

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A new kind of giant

Desiree Willis, of the Robbins Corporation, explains the current state of works on China's Jinping II mega hydropower project

"Jinping-II is one of the most understated tunnelling projects in the world today. The planning and organization are probably equal to if not greater than the Channel Tunnel."

Steve Chorley, Robbins field service manager at the jobsite, based his statement on the project's 30+ years of development and planning and the remote location in China's Sichuan Province - over two hours away from the nearest city. The Jinping-II Hydroelectric Project involves infrastructure planning and development on a massive scale, requiring four 16.7km long headrace tunnels, auxiliary tunnels, and powerhouse structures, all supported by a provisional town of 20,000 workers from China and around the globe.

As of October 2008, work is ongoing on the powerhouse structures as well as the four headrace tunnels - two are being excavated by drill and blast and two by 12.4m diameter TBMs. A total of three TBMs, two of them Robbins, were launched in summer 2008 for work on headrace tunnel nos. 1 and 3 and an additional 15.3km long dewatering tunnel.

Project overview

Jinping-II will be the largest power station in an ambitious 21-station project for owner Ertan Hydropower Development Co. Ltd. The project will harness up to 25 million MW per year from the Yalong River for China's West to East Electricity Transmission Project. Power from these stations and other resources in the west will be transmitted to Guangdong, Jiangsu, and Zhejiang Provinces, as well as the cities of Shanghai, Beijing, Tianjin, and other eastern locations in short supply. The entire scheme is envisaged to go online in 2030.

"This project has been ongoing for the past 40 years, as far as preliminary geological surveys, feasibility studies, and necessary approvals for large scale development," said a senior technical engineer from Ertan. Beginning in 2000, work was completed on the Ertan Hydropower Station, with a 3300MW annual generation capacity. In 2003, work began on the 62km long main road leading up to the Jinping-II jobsite. By 2006, the site of the Jinping-I station, located 17km downstream, was dammed off. The Jinping-I station is slated for completion in 2014 and will have an annual generating capacity of 3600MW.

The Jinping-II site is unique in that it will utilize a natural 180 degree bend in the Yalong River, a tributary of the Yangtze, to generate 4800MW annually. Four headrace tunnels will travel at a 3.65% downgrade from intake structures near Jingfeng Bridge to the underground Dashuigou powerhouse, which will utilize eight hydraulic turbine generators. The parallel headrace tunnels, each 16.7km in length, are separated by 60m from centreline to centreline. Two access tunnels and a drainage tunnel run parallel to the headrace tunnels on the southern side.

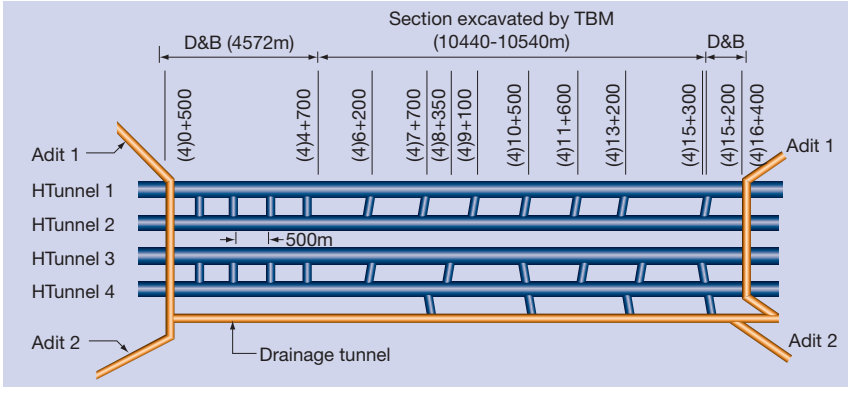
"The Chinese economy will benefit immensely from the Jinping-II project. There is a 320m head of water between the inlet and outlet areas of the tunnels, enabling a huge amount of power generation annually," said the Ertan technical engineer. The owner elected to use two 12.4m TBMs, one Robbins Main Beam Machine (headrace tunnel no. 1), and one Herrenknecht machine (headrace tunnel no. 3). The tunnelling and D&B work is split into two contracts - China Railway 18th Bureau (Group) Co Ltd. is responsible for headrace tunnel nos. 1 and 2, while China Railway 13th Bureau (Group) Co Ltd are constructing headrace tunnel nos. 3 and 4.

The parallel 15.3km long dewatering tunnel being excavated by a 7.2m diameter Robbins TBM is being managed by Beijing Vibroflotation Engineering Company (BVEC), and will be excavated ahead of the four main tunnels in order to alleviate expected water inflows of up to 5m^3/sec.

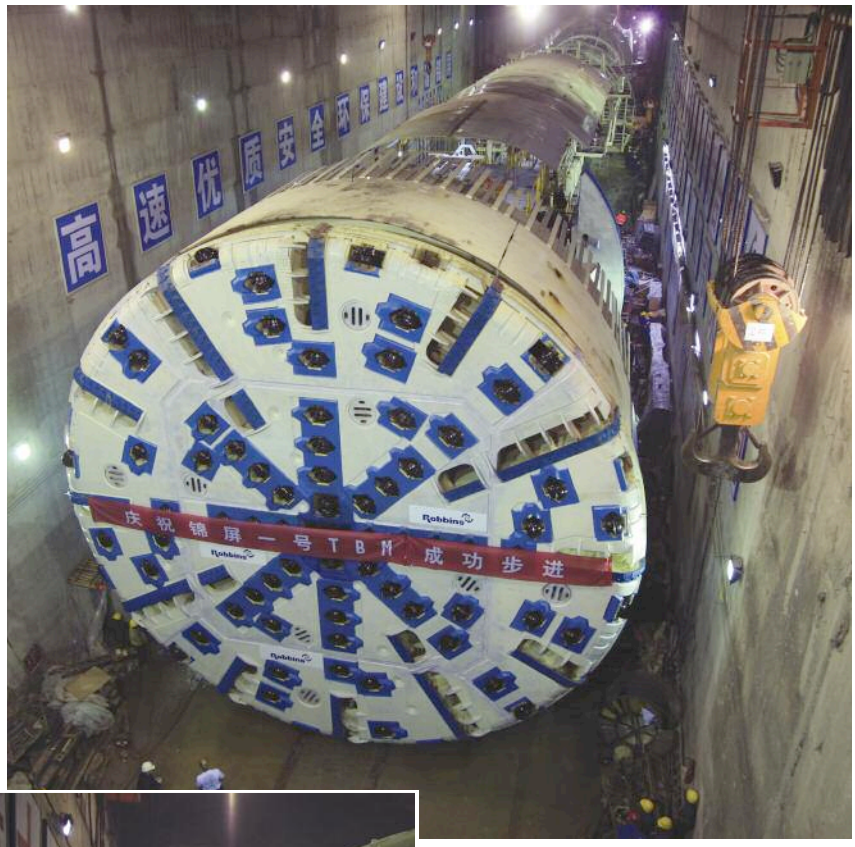
Right: **Fig 1 – Location map**

Challenging logistics

Much of the challenge at the jobsite has been a result of the remote location. Onsite First Time Assembly (OFTA) was elected due to project scheduling and difficulty in shipping large pre-assembled TBM components. The OFTA process, developed by Robbins, allows machines to be initially



Right: **Fig 2 – Plan map of the tunnels**



Above: The 12.43m diameter Robbins TBM began boring in mid-October 2008
Left: Robbins designed the back-up system with a steel shield to deflect heavy water inflows

assembled at the jobsite without pre-assembly in a manufacturing facility. The overall process results in savings due to decreased shipping costs and man hours.

OFTA enabled large TBM components to be shipped via barge on the Yangzi River, ahead of the low water season between November and April. The area sees vastly different seasons, with the May to October rainy season accounting for as much as 95% of the annual rainfall.

Once at the site, the 12.4m machine was erected in an underground assembly chamber measuring 20m wide x 26m high. Limited space required that many of the TBM components be staged about 80km away in the town of Manshuiwan, where warehouse space and a large outdoor yard were located.

Assembly of the TBM and back-up system began in July 2008 and finished on September 17. Crews then walked the TBM and the first three back-up gantries 200m forward from the assembly chamber to a launch chamber. The vacated chamber was then used to erect the conveyor system and six more back-up gantries.

Both Robbins machines were successfully assembled despite record snowstorms, as well as this year's devastating earthquake in Chengdu, which caused some delays to the schedule.

Designing for heavy water inflows

All four tunnels are located in relatively stable geology consisting of massive, blocky marble with limestone and sandstone between 50 and 85MPa UCS. A high overburden, with over 70% of the cover above 1,500m and a maximum of 2,525m, creates a risk of squeezing ground, however. In addition, preliminary core tests showed several faults and fractures, as well as karstic patterns with water bursts at a pressure of up to 2.4MPa in some sections. These same core tests revealed maximum water flows of up to 5m^3/sec, with steady flows of 2 to 3m^3/sec.

In response to the core tests, an aggressive ground support program has been developed based on the rock mass classification.

"These tunnels are under very high stress and high cover at a large diameter. This is a significant and challenging project for the Chinese tunnelling industry," explained the Ertan senior engineer. In relatively stable rock, support is minimal including sparse rock bolts. In rock mass Class III, systematic rock bolts up to 6m long are installed, as well as steel-fibre reinforced shotcrete. Class IV and V sections are stabilized with a permanent concrete lining up to 70cm thick, as well as rock bolts and reinforced shotcrete.

Robbins specially designed the 12.4m diameter TBM for high water inflows and difficult ground conditions. The entire TBM, back-up, and continuous conveyor setup in the tunnel are raised 1.5m above the invert on a continuously installed steel framework, allowing the expected large water inflow to pass under the back-up. Portions of the back-up are also covered by an arched steel cover to further deflect inflows. In addition, a water discharge pump can relay water from the cutterhead support to the end of the back-up. Reserve saddles located under the gage area on the TBM cutterhead allow for over-boring up to 250mm if squeezing ground is encountered. TBM modifications in the dewatering tunnel are much the same.

Muck will be transported from all tunnels by continuous conveyor to a nearby storage site. For the headrace tunnels, a Robbins continuous conveyor system, 15.4km in length, handles muck from both headrace tunnels 1 and 2 before dumping onto a customer-supplied overland conveyor. The steel cable belt system utilizes a 1,200kW main drive in addition to a 1,200kW booster drive, and is capable of transferring 1,800 metric tons per hour. The dewatering tunnel utilizes a similar steel cable belt system 15.4km in length.

Current state of work

The assembly of both 12.4m machines was completed in Autumn 2008, while the

Right: An additional 7.2 m Robbins machine is boring a dewatering tunnel ahead of the headrace tunnels

7.2m machine was launched earlier in May. As of late October, the Robbins machine at headrace tunnel no. 1 was undergoing continuous testing and had advanced more than 10m of its 2,000m long commissioning bore. Increased ground support at the interface between the starting chamber and the bored tunnel was still being fine-tuned, including ring beam installation every 900mm and a comprehensive 17-bolt pattern of rock bolts every 1.5m.

Excavation at the dewatering tunnel has advanced a total of approximately 1,400m, at rates up to 42m per 10-hour shift. Operations at the drill and blast tunnels were also underway and had advanced approximately 2km in headrace tunnel nos. 2 and 4.

The TBM for the dewatering tunnel is expected to finish in late 2009, while the machine at headrace tunnel no. 1 is slated for a mid-2012 breakthrough. Although Ertan's entire hydropower scheme will not be finished until 2030, the construction of the Jinping-II hydropower station is a feat in its own right. "This is one of the biggest TBM-driven tunnelling projects in Chinese history," said Biyue Li, Robbins Chief Operational Officer, Far East. "This is one of many ongoing projects for the country. China is currently one of the leading TBM markets, and will be for at least the next five to ten years." T&T

Speed up a long way.

Niagara Falls/Canada. For the construction of the 10,500m long Hydro Power Tunnel the conveyor providing company H+E supplies a continuous conveyor system allowing a fast transport of the excavated material. One Booster is used to reduce the forces exerted on the belt along the route; with the pleasant side effect to guide the belt save in front of a vertical curve.

The naked facts:

Tunnel diameter:	14.4m
Conveyor length:	10,500m
Belt width:	1,000mm
Capacity:	1,600 t/h
Installed power:	4 x 360kW (head) 2 x 360kW (booster)
Belt storage capacity:	600m of belt
TBM:	Hard Rock Gripper
Installation:	2006
Contractor:	Strabag Inc.

H+E LOGISTIK GMBH

H+E Logistik GmbH
Weg am Kötterberg 11a
D-44807 Bochum
Germany
phone + 49 (0)234 | 950 23 60
fax + 49 (0)234 | 950 23 89
www.helogistik.de

Soil conditioning for EPBMs

Raffaele Vinai, Luca Borio, Daniele Peila, Claudio Oggeri and Sebastiano Pelizza, of the Department of Land, Environment and Geo-engineering, Tunnelling and Underground Space Centre; Politecnico di Torino (Italy) discuss recent research into soil conditioning for EPBMs

Earth Pressure Balanced shields are nowadays used more and more due to both the mechanical development of the machines and the more effective use of additives (mainly foams and polymers). These additives are typically injected into the chamber and through the face of the machine cutting wheel in order to condition the ground. Less frequently they are used to condition spoil in the screw conveyor or used post excavation to facilitate transportation, disposal.

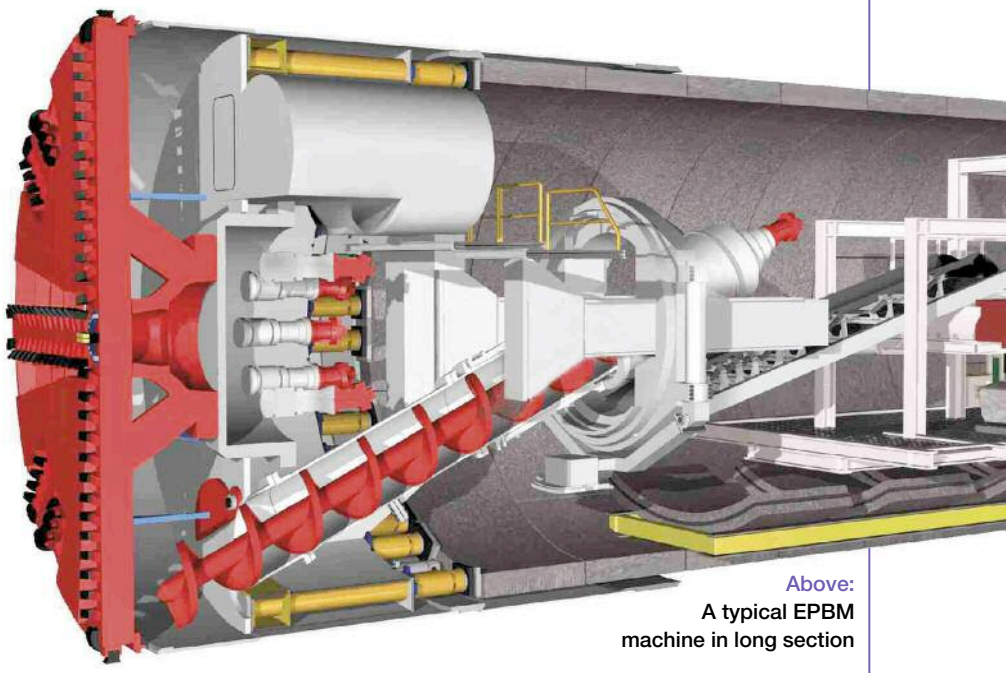
Despite its great importance very little experience on soil conditioning exists, particularly for cohesionless soils, and no standardized tests are currently available for comparing various types of products and conditioning set up.

Usually the amount of conditioning agents used are chosen directly on the job site based on a trial-and-error procedure.

As EFNARC in its 2001 guidelines clearly states: "At present soil conditioning in soft ground tunnel boring machines remains very much a "black art" determined largely by experience or trial and error. This is no implicit criticism but represents the reality in the industry where there has been little formal research into the key parameters". While in the updated EFNARC guidelines (2005) no references are given to tests which should be carried out on conditioned soils, but only tests to characterize the foam (foam half life, effect of plasticizing action of a foam, foam/sand mixture half life).

Among the studies concerning ground conditioning the following should be mentioned:

- Kuribashi et al. (1993), Herrenknecht and Maidl (1995) offered a qualitative quantification of the effect of foam and Milligan (2001) developed a state-of-the-art procedure with specific reference to microtunelling applications
- Peron and Marcheselli (1994), Quebaud et al. (1998), Bordachar and Nicolas (1998), Jancsecz et al. (1999), Williamson et al. (1999), Peña (2003), Boone et al. (2005), and Vinai et al. (2006) used the slump cone test to characterize the soil plasticity
- Bezuijen and Schaminée (2001) studied the behaviour of conditioned sand soils with both a full-scale and a laboratory model screw conveyor
- Yoshikawa (1996) performed a number of tests using a full-scale EPB screw conveyor with plastic soil and with different screw speeds
- Merritt and Mair (2006) developed a laboratory screw conveyor device to test the extraction of soil from a tank with a sub-horizontal screw and carried out 16 tests on clay samples. This laboratory device was made up of a pressurized tank connected to a 1m long x 0.1m diameter horizontal screw conveyor which was calibrated to measure the torque and the total stress, and the pore water pressure, in four sections



Above:
A typical EPBM machine in long section

From the above chronology of previous research, it appears clearly that the trend for the study of the soil conditioning is to develop and use a test able to simulate the extraction of earth from the chamber with a screw conveyor. This is because only this procedure can provide quantitative parameters able to really describe the conditioned soil behaviour.

A facility of this nature has been developed at Politecnico di Torino with the support of MAPEI SpA (UTT Department) and is described in the following.

The experimental apparatus

The laboratory device represents an approximate 1:10 screw conveyor scale model with a screw length to diameter ratio of nine.

The device comprises an 800mm high tank with a 600mm nominal inner diameter which is filled with soil. An aluminium plate connected to a hydraulic jack, with a stroke of 500mm, applies a nominal pressure to the tank of up to 2MPa, which is the value that can be encountered in a number of urban tunnels at a depth of 10-20m. A 1500mm long screw conveyor is coupled to the tank with an upward inclination of 30° which is the average value usually used in EPB machines and the screw extends inside the tank to collect and extract the soil. The diameter of the screw case is 168mm, the flights have a pitch of 100mm and the screw shaft has a 60mm diameter.

The laboratory device was fitted with the following instrumentational sensors:

- three total pressure cells (numbers 1, 2 and 3) to measure the total normal stress applied along the screw conveyor case. They consist of load cells with a 50mm diameter rounded pad that fit into the screw casing. The cells are spaced at 250mm and the first cell is 430mm from

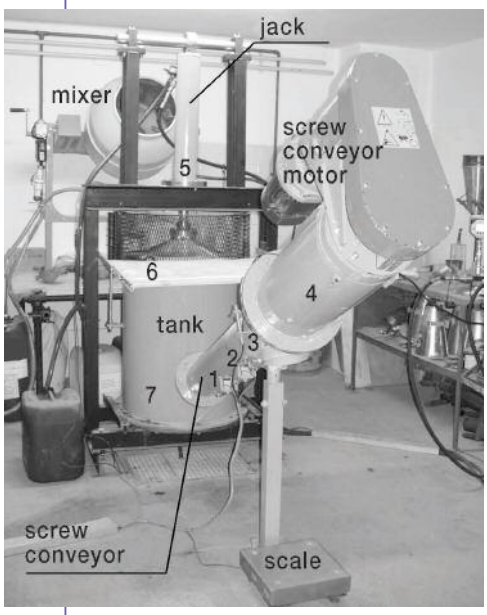
the tank base
- a torque meter, in line with the screw shaft, to measure the torque transferred from the motor (number 4)
- a displacement wire transducer to control the upper plate movement (number 5)
- two total pressure cells with a diameter of 114mm to measure the load under the upper plate and on the bottom of the tank (numbers 6 and 7)

The foam used for the soil conditioning is obtained from an industrial foam generator adapted for laboratory purposes. This allows the conditioning liquid flow and air flow to be controlled and the foaming agent concentration is electronically controlled.

Preparation and procedure

The soil sample is prepared by mixing 25kg of soil with known moisture in a concrete mixer with the required amount of foam. The mixer bowl is then turned for 120 seconds and the conditioned soil is poured into the tank. This operation is repeated until the tank is full (about 350kg of conditioned earth is necessary for each test). The upper plate is then positioned and pushed down by the jack until the test pressure is reached in the tank. The screw conveyor is then started and the material is collected and weighed at the discharging outlet. During extraction, the upper plate is pushed downward to maintain constant pressure in the tank. The test is stopped when the piston reaches its maximum stroke.

Below: Photograph of the laboratory screw conveyor device. Installed sensors include: 1-2-3) pressure cells along the screw conveyor; 4) torque-meter 5) displacement of the upper plate wire transducer; 6) tank upper pressure cell; 7) tank bottom pressure cell



Conclusions

Ground conditioning is a crucial component of EPB tunnelling applications. It is, therefore, of primary importance to design and construct reliable laboratory test procedures that are able to permit quantitative measurements of the conditioned ground behaviour, particularly when working with cohesionless soil.

A reliable test procedure can only be carried out using a laboratory device which can simulate the EPB extraction procedure from the bulk chamber using a screw conveyor. This type of device can be a reliable tool for the study of the conditioned soils since it permits the measurement of parameters which are directly linked with the full-scale machine performance, namely: torque on the screw, ability of the material to transmit a pressure, possibility of homogeneous flow, and pressure control along the screw conveyor.

To show a summary of the results which can be obtained with the device, the diagrams of the torque, pressure in the tank and along the screw, for two types of soil (the soils are provided by MAPEI SpA) where EPB tunnels were excavated (Brescia and Torino metros) are presented on p27. T&T

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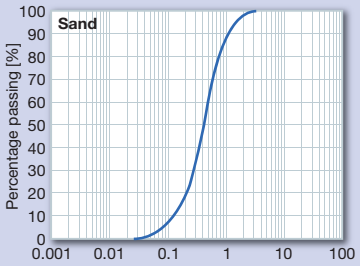
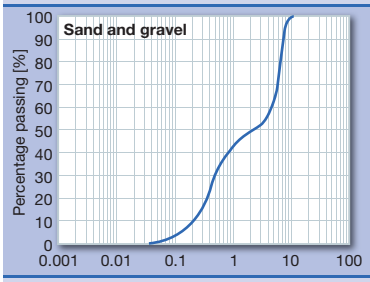
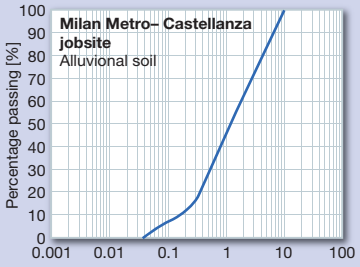
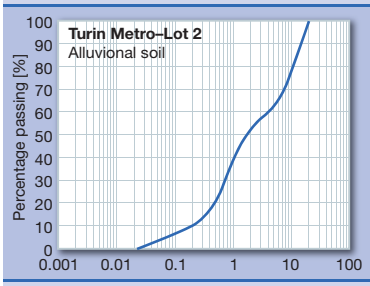
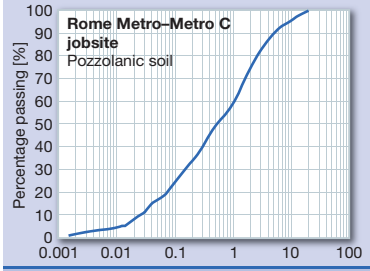
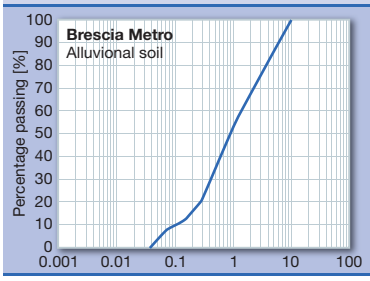
Soil	Conditioning agent	Test parameters	Pressure in the tank [kPa]	Torque during regular extraction [N*m]	Pressure along screw [kPa]	Extraction speed [kg/s]
	PolyFoamer FP Agent concentration: 2%	FIR = 40% FER = 17 w = 10% Screw speed: 6 rpm	Theoretical top pressure: 90 Measured top: 80/95 Measured bottom: 90/100 Good transmission of the pressure	6 – 10	Cell 1: 20-23 Cell 2: 12-14 Cell 3: 4-6	0,183
			Theoretical top pressure: 90 Measured top: 60/80 Measured bottom: 60/80 Average transmission of the pressure	8 – 10	Cell 1: 23-28 Cell 2: 12-17 Cell 3: 4-7	0,193
	No conditioning	Saturated sand Screw speed: 6 rpm	Theoretical top pressure: 90 Measured top: 90/150 Measured bottom: 75/85 Bad transmission of the pressure	35 – 40	Cell 1: 4-6 Cell 2: 7-9 Cell 3: 2-4	0,145
	PolyFoamer FP Agent concentration: 2%	FIR = 40% FER = 17 w = 8% Screw speed: 6 rpm	Theoretical top pressure: 90 Measured top: 75/80 Measured bottom: 70/75 Average transmission of the pressure	8 – 10	Cell 1: 35-30 Cell 2: 22-18 Cell 3: 8-5	0,210
	No conditioning	Saturated soil Screw speed: 6 rpm	Theoretical top pressure: 90 Measured top: 50/60 Measured bottom: 50/60 Bad transmission of the pressure	25 – 30	Cell 1: 6-8 Cell 2: 4-6 Cell 3: 2-4	0,137
	PolyFoamer FP Agent concentration: 2%	FIR = 25% FER = 16 w = 10% Screw speed: 6 rpm Cut off value of the grainsize: 20mm	Theoretical top pressure: 90 Measured top: 55/80 Measured bottom: 65/80 Average transmission of the pressure	20 – 40	Cell 1: 20-25 Cell 2: 17-20 Cell 3: 6-8	0,246
	PolyFoamer FP Agent concentration: 2%	FIR = 25% FER = 18 w = 7% Screw speed: 6 rpm cut off value of the grainsize: 20mm	Theoretical top pressure: 90 Measured top: 45/55 Measured botom: 65/75 Good transmission of the pressure	40-50	Cell 1: 9-12 Cell 2: 8-10 Cell 3: 3-5	0,136
	No conditioning	Saturated soil w = 12% Screw speed: 6 rpm Cut off value of the grainsize: 20mm	Theoretical top pressure: 60 Measured top: 25 Measured bottom: 25 Bad transmission of the pressure	It was not possible to extract the material from the tank		
	PolyFoamer FP Agent concentration: 2.5%	FIR = 20% FER = 18 w = 30% Screw speed: 6 rpm	Theoretical top pressure: 120 Measured top: 115 Measured botom: 100 Average transmission of the pressure	10-12	Cell 1: 25-15 Cell 2: 20-10 Cell 3: 15-8	0,178
	No conditioning	w = 30% Screw speed: 6 rpm	Theoretical top pressure: 120 Measured top: 150 Measured bottom: 75 Bad transmission of the pressure	It was not possible to extract the material from the tank		
	PolyFoamer FP Agent concentration: 2%	FIR = 35% FER = 10 w = 11% Screw speed: 6 rpm cut off value of the grainsize: 20mm	Theoretical top pressure: 90 Measured top: 50/75 Measured botom: 65/90 Good transmission of the pressure	50-60	Cell 1: 27-33 Cell 2: 16-19 Cell 3: 9-11	0,233

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From woe to go

Barbara Stack, author of the Encyclopaedia of Tunnelling, Mining, and Drilling Equipment describes the birth of recessed and back loading cutters

The story of recessed and back-loading cutters, which is integrated with the evolutionary development of Mixed Ground TBMs, commenced some forty years ago. It began with the California State Water Project in the U.S.A. then moved to a project in Melbourne, Australia, to Sila in Italy and from there to the Buckskin Mts Project, U.S.A. From Buckskin to Russia, finally ending with the Selby Project in the U.K.

Diverse ground on the California State Water Project tunnels, influenced the development of shield excavators which had some degree of flexibility built into their basic design. This enabled them to cope more readily with anomalous terrain.

In the same way, in their turn, did the Melbourne & Metropolitan Board of Works south-eastern trunk sewer tunnels in Melbourne, Australia, inspire the design of the first hard rock hybrid machine. However, there was one important difference; the M.M.B.W. had, to some extent, a forewarning of the type of country which would be met along the way. Test holes indicated, with some accuracy, the various types of ground conditions which could be expected. They showed that water-bearing Tertiary sandy sediment over Silurian bedrock lay in the Kew to Moorabbin tunnel route, while mud and sandstone strata was expected in other sections. There were also indications of badly faulted and fractured siltstone, blocky sandstone and plastic clay. Lightly fractured sections of fairly good cohesive material were interspersed with areas of soft running ground and bands of heavily fissured rock combined with soft sticky clay. To say the least, a very discouraging picture.

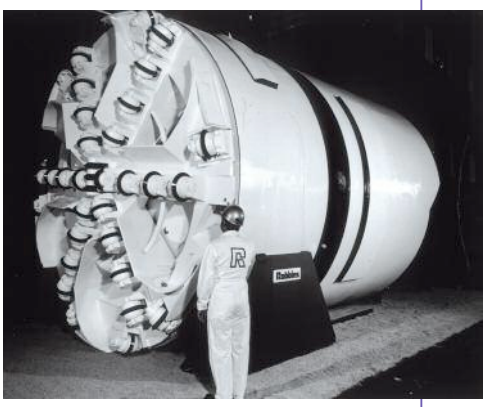
In addition to the provision of a canopy or shield, mounted over the cutterhead and extending as far as the tunnel spring line, the Robbins machine used for this job was fitted with a domed boring head. This latter component, with its protruding cutters was unsatisfactory when blocky material was encountered. Instead of crushing and removing the spoil as they had been designed to, the cutters tended to grab the material in chunks and pull it across the face. The net result was that unstable ground ahead of the TBM was disturbed in much the same manner as had occurred in the first section of the California State Water Project's Newhall Tunnel.

Taking note of suggestions put forward by the Board's staff – in particular Frank G. Watson (Workshops and Plant Services Engineer) and Alan J. Neyland (Project Engineer), the problem was finally solved by the replacement of the domed head, sliding support and steer shoes at the front of the machine, with a new revolving spoked-wheel type cutterhead, and a full circle flexible slotted shield which rapped completely around the cutterhead support. This important component, which was manufactured in Australia, later came to be known as the 'Melbourne-type' head.

Later, when a TBM was required for the Orichella and Timpagrande tunnels in Sila, Southern Italy, with ground conditions ranging from 69 to 207MPa, it was realized that two types of TBM would be needed – namely, a mechanized shield for those sections where the ground was unstable, and a machine with side wall grippers for those areas where the rock fell into the higher compressive strength range.

Obviously the purchase of two TBMs would be costly. To meet the situation Carlo Grandori, at that time, Managing Director of the Italian company S.E.L.I., suggested that the Robbins Company should design and build them a special prototype TBM embodying, in one unit, as many of the essential characteristics of the two types of machine as was practicable.

Following the Melbourne and Metropolitan Board of Works' experiences in Australia, Carlo Grandori decided to equip the Italian machine with a 'Melbourne-type' cutterhead, to enable it to cope with the anticipated sections of fractured and blocky strata which lay ahead. It featured an open six-spoked



Right: **Robbins 'Grandori' tandem mechanized shield**
Below: **The Robbins Melbourne machine as supplied**

wheel-type cutterhead fitted with one tri-disc and 28 disc cutters.

The expression 'one man's meat is another man's poison' might be aptly applied to the two Projects; i.e. the one in Melbourne and in Italy. In both cases badly fractured and blocky ground was anticipated and encountered. However, in Melbourne, this was mostly Silurian mudstone and sandstone, whereas in Italy it comprised Sila granite – a much harder substance, and perhaps therein lay the difference.

Grandori reported that hard boulders were found embedded in a softer matrix in some sections of the badly fractured Sila Granite formations. Large pieces of rock frequently fell from the face in these areas. They passed through between the spokes and jammed themselves firmly behind the cutter arms, where they caused extensive damage to the muck loading and conveying system. When this occurred the wedged rock had to be manually broken and removed, a costly and time-consuming operation.

The situation was tolerated until the machine entered a particularly bad area and a major face collapse jammed the cutterhead preventing further progress. This induced Grandori and his team to remove the cutterhead and effect suitable modifications to it which, hopefully, would enable the machine to proceed more efficiently. Basically the modifications consisted of closing up the large gaps, which existed between the cutting arms, with heavily welded steel bars arranged concentrically between the spokes. These formed a strong grille or screen which prevented rock fragments measuring more than 8 inches in diameter from passing through into the muck-handling and conveying equipment. The completed grille-work was approximately an inch from the tunnel face which, in Grandori's opinion, was the key to the modification's success, as this distance represented the average depth of rock spall produced by the disc cutters.

The development of the Robbins TBM for the Buckskin water tunnel in Arizona came as a direct result of Grandori's experiences with the tandem shield in Italy. The Buckskin machine was a 7.16m diameter completely shielded rock boring machine consisting of two shields which telescoped together for the boring stroke and yet were flexible enough to permit normal steering control.

According to Eugene G. Murphy (Manager for the Buckskin Mts. Project) the tunnel started in well-cemented Andesite rock formation which varied from 2m cube blocks to crushed material, visicular Andesite, agglomerate and tuff. However, as the tunnel progressed, the calcite and gypsum cementation between the blocks was replaced by clay, or the interfaces became completely devoid of any adhesive material. At the 460m mark the overbreak was seen as some 6m high.

The collapse of large blocks caused structural damage to the machine, constantly plugged the muck hopper and affected the general stability of the TBM.

As Murphy so aptly described it, the TBM was, in effect, acting as a giant horizontal blender, no work being performed by the cutters other than the mixing action. Although cutter wear was minimal, the cutters were nevertheless failing structurally due to their impact with blocks of rock. To overcome these problems the cutterhead face was advanced a distance of a foot and the consequent gap between the new plate and the original cutterhead was filled with a cement grout, so that the thrust against the new cutterhead could be handled.

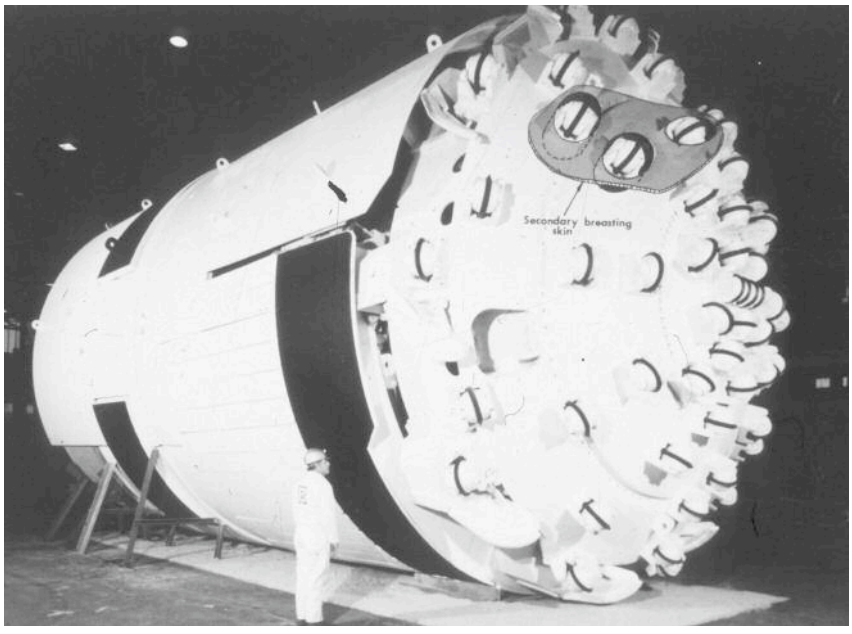
A ring made from 24 inch diameter pipe, with inch thick walls was welded around each cutter, the edge of the pipe being trimmed to fit it to the spherical shape of the cutterhead. These and other modifications including circumferential rings that were welded to the cutterhead between the outer gauge cutters and the inner circle of cutters, and the provision of block-outs around the gauge cutters and muck buckets all formed part of the secondary breasting skin arrangement tried in the Buckskin tunnel.

Although the problem of overbreak and blocking appeared to have been solved, a new difficulty became apparent. The shield skin plate designed with a horizontal joint 3ft below the spring line, was now being deflected by the blocky ground at the crown and sides. This deflection was severe enough to hinder the erection of segments within the tail shield. So, once again, the machine was stopped to enable five stiffener beams to be installed in the tail shield skin plate, while the plate itself was increased in thickness from 1 to 1½ inches. Blocky, soft and various grades of ground in between were then successfully handled by the TBM.

As a result of the experiences gained on the Buckskin Project the cutterhead of the Robbins fully shielded hard-rock machine destined for work in Russia during 1979-82 featured cutters protected by breasting plates and rings. But, later, when the Robbins' Selby machine was commissioned, it was note-worthy because it was the first full-face TBM with recessed cutters and was also the first to use rear change or back loading cutters.

Having moved from projects in Melbourne, Sila, and Buckskin to ones in Russia and the U.K. as we traced the evolutionary development of hybrid machines, we now return to the S.E.L.I. company and the DSU-TBM produced by them in 2001 to cope with a wider range of ground conditions than could be handled by conventional single-mode TBMs. Its basic features included the ability to adjust the excavation diameter of the cutterhead, cope with squeezing ground, treat the ground ahead through the face and operate in single or double shield mode. That unit led to the development of the SELI-DSU/EPB TBM.

The most significant component of this

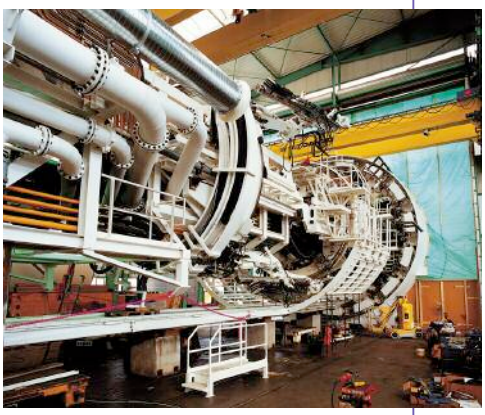


Left: **Depicting part of the secondary breasting skin arrangement tried in the Robbins Buckskin TBM**

latter unit was its cutterhead, which was designed to be converted from DSU to EPB and vice versa, while in the tunnel. It consisted of bolted plates fitted between the cross arms, thus closing the gaps separating them. This allowed the machine to operate in rock-cutting mode. Recessed cutters were mounted on the cross arms. When the machine was operated in the EPB mode the plates between the cross arms were removed. The gaps thus created then permitted the ingress of material to the drum-chamber, situated immediately behind the cutterhead arms. In this mode an auger or screw conveyor was fitted to the invert for the removal of the compressed material in the drum chamber, in much the same manner as a conventional EPBM would operate. Where coarse granular material was encountered the machine could be converted into a Slurry unit by injecting fines into the hyperbaric chamber, thus further extending the use of this type of TBM.

Recently a 3.1m diameter Robbins unit with the capability of conversion from soft ground EPBM to medium/hard rock TBM was constructed for Wastewater Tunnels in Istanbul. The machine used disc cutters and a conventional belt conveyor for medium to hard rock strata or tungsten-carbide drag bits and a screw conveyor for soft ground.

And finally when the Swedish/French JV of Skanska/Vinci and Herrenknecht AG were confronted with the very difficult mixed ground terrain prevailing beneath the Hallandsås ridge, they designed a special TBM to handle these complex strata. Dubbed the 'Asa' the unit was capable of operating in either the open mode as a hard rock machine with a conventional TBM spoil conveyor or in the closed mode as a Mix-Shield with slurry removal to a surface treatment plant. The Mixshield evolved from the 'Hydroshield' and 'Hydrojet Shield' slurry machines introduced by Wayss and Freytag Ag during the early 1970's. This 'convertible' unit was developed in conjunction with Herrenknecht GmbH (who was the Licence Holder of the Wayss and Freytag Mixshield' patent). Its main purpose was to be able to rapidly convert the machine, in long runs, to varying modes so it could handle a wide variety of soil conditions. These transformations needed to be rapid and, if possible, undertaken underground within the narrow confines of the tunnel itself. It was envisaged that such a unit should be capable of being changed to the slurry, earth pressure, or dry mode of tunnelling, with or without compressed air. T&T



Right: The Herrenknecht TBM for the Hallandsås Project

Role of the Expert Witness

Aside from being involved as a party, the other way that engineering professionals might become involved in a formal dispute resolution process is by being appointed as an expert witness. Paul Cullinan of Nexus Contract Services Ltd outlines the role, and some of the tensions which can arise in the fulfilment of that role

The deployment of expert evidence can be a very costly exercise and so one would only see such an appointment in the most formal of processes, that is, either in litigation in the courts or in arbitration. In common law, adversarial legal systems there will be a tendency for each side to appoint its own experts, in civil law jurisdictions there is more of a willingness to have court-appointed, or in arbitration, tribunal-appointed experts. The relative merits of the two approaches is dealt with later. Remaining with the scenario where each party appoints its own experts, depending on the case being put, there will likely be several experts on each side dealing with their own specialisation. In a typical tunnelling project action therefore there could be experts for delay analysis, quantum (money), geotechnical, equipment, linings and many others.

Misunderstandings and tensions

The role of the expert can often be misunderstood and particularly by the lay-members of a party's management where the perception may well be that, 'we are paying good money for this person's opinion, so that opinion had better support our case!' If it were ever the case that an expert was simply the 'hired gun' of the party then that is certainly not the case in modern practice in litigation and arbitration where it is clear that an expert's overriding obligation is to inform and advise the court or tribunal in his or her given area of expertise. Note that this includes even where that opinion may be adverse to the case being presented by the party paying the expert's fees.

This tension can be added to by a parallel role that an expert may perform which is one of acting as a party's 'candid friend', that is, giving honest opinions outside of the dispute forum on the relative strengths and weaknesses of the party's case. It is fair to say that it takes some amount of skill on the part of an appointed expert to draw the fine line between these potentially competing roles.

My own way of resolving some of these misunderstandings and tensions is to explain to lay clients that, certainly in modern practice, if an appointed expert is seen to be acting with bias or as simply as another advocate of the party's case then it is likely that the experts testimony will either be given less weight or in some cases

MISCONCEPTION NO1 - "WE ARE PAYING GOOD MONEY FOR THIS PERSON'S OPINION, SO THAT OPINION HAD BETTER SUPPORT OUR CASE!"

"THERE IS A BODY OF OPINION THAT SAYS THAT THE TRUE EXPERTS ARE THOSE WHO DO THE JOB DAY-IN-DAY-OUT, NOT SOMEONE WHO IS ON THE EXPERT WITNESS 'CIRCUIT"

disregarded altogether. Seen in this light it is the expenditure on an over-partisan, rather than independent, expert which would be a waste of the client's money.

Single joint expert

The proposal to use court/tribunal appointed experts can therefore seem like an obvious saving of expense, why have two opposing experts (or more in multi-party litigations) in each discipline when one can have one expert feeding in, what in any case, needs to be impartial advice? There is some merit in that view and as noted previously is a route taken more often in civil law jurisdictions where a judges/arbitrator's role is much more inquisitorial than the adversarial approach taken in common law actions. There are three counters to the argument. Firstly, it is unlikely that a judge/arbitrator would go against any advice, on technicalities at least, given by the court/tribunal appointee, in heavily technical construction and engineering disputes then there may seem little point in the expense of involving the judge/arbitrator at all when one could go directly to the expert for the answer, indeed there is facility for such dispute resolution known as 'expert determination'. Secondly, insofar as the common law adversarial system is concerned at least there is much suspicion and resistance to so much weight being given to a single expert without the ability to question that expertise. Thirdly, court/tribunal appointees are unable to fulfil to the same extent the very valuable role of party appointed experts in narrowing the issues in dispute, this contribution is dealt with in further detail below.

Value added by party appointed experts

Great value can be realised by party appointed experts narrowing the issues which need to be decided by a court or arbitration tribunal. By approaching matters with the necessary measure of impartiality experts can, through a series of expert-to-expert meetings prior to a hearing, come to agreements where they can on technical matters. The more that can be agreed in these sessions the less is left to be argued in full in court or in an arbitration hearing with consequent significant savings in the time and expense of those hearings. This is particularly so in the case of the quantum experts who can reach agreements on what a particular issue is worth in monetary terms on a 'figures-as-figures' basis, leaving the judge or tribunal to decide only on the principle without having to delve into the minutia of the figure-work. Of course close liaison is required between the expert and the party's lawyers/dispute managers to make sure that the client knows what concessions are being made on its behalf.

Considerations in taking expert appointment

Whilst many construction and engineering professionals see getting into expert witness work as a lucrative option, careful consideration should be given before accepting appointments as an expert. Firstly, it should be ensured that there are no conflicts of interest between the expert appointment and other work being carried out by the expert themselves or their firm. This sounds straightforward enough but when one undertakes such a conflict review one realises how closely inter-connected everyone is in a specialist sector such as tunnelling. Whilst other assignments being undertaken by colleagues in a firm will not automatically preclude taking an expert appointment, a potential expert should make known all such potential conflicts to the prospective client; imagine the scenario where such potential conflicts are not declared and several months later when, having already expended much effort and collected substantial fees, the conflict then becomes a real issue.

Secondly, a potential expert should really question whether he or she has the necessary expertise in the area under dispute, there will be a continuing duty for the expert to keep this aspect under review and as the case develops in order to avoid 'mission creep', that is holding oneself out as having, or being persuaded that one has, sufficient expertise to give testimony on a matter which is in truth outside of one's professional experience. Aside from this duty to one's client any lack of expertise will soon become apparent under cross-examination.

An appointed expert must become thoroughly familiar with all the aspects of a case relevant to his or her area of expertise, that will mean reading all the relevant pleadings in the case, relevant witness statements from witnesses of fact and of course the reports and testimony of opposing experts. An expert must continually test their own opinions in the light of all such other submissions and testimony and have the courage of his or her convictions to change that opinion in the light of new submissions or evidence.

Familiarity with process

Whilst an expert is obviously called to give his or her professional opinion some familiarity with the dispute resolution process, be it in court or arbitration, is necessary. Some guidance will be given by the lawyers but there is an onus on the expert themselves to do either their own reading on the subject or indeed attend one of the many courses organised for the training in the role of expert witness. In an arbitration an understanding of the context of that arbitration will be required by way of familiarity with the rules under which the arbitration is being conducted and relevant parts of the arbitration law of the 'seat' of the arbitration. In litigation there are likely to be court procedural rules dealing with the giving of expert evidence, for example in England this will be according to the Civil Procedure Rules (CPR), Rule 35 of which, together with its Practice Directions stipulates the requirements for the giving of expert testimony in the High Court.

Professional reputation at risk

A potential expert might also wish to consider their professional reputation before embarking upon the giving of expert testimony. Any report or statement submitted by the expert will be the subject of cross-examination by the other side, that will of course mean the expert being on the witness stand in front of the court or tribunal and being subjected to questioning by the opposing side's lawyer. It is fair to say that the priority of such advocates will be to get a 'result' for their client even if that means seeking to undermine the expert's professional reputation in the process, it is not personal, it just seems that way! On occasions too, some judges have taken it upon themselves to completely pillory individual experts on their testimony, these comments will make their way into the published law reports for all the world to see, and I suppose because of the personal nature of such attacks these types of judicial comment gain almost instant notoriety. Whilst this type of judicial censure will usually be reserved for those experts who have acted contrary to the expected standards of independence they do cause an obvious black mark against a professional persons reputation.

Further, one should guard against undertaking too much expert work or one might get the reputation of being a 'professional expert', that is someone who only does expert witness work and seldom

if ever actually does any work in his or her professed field of expertise. There can be a tendency by the lawyers in particular to place over-emphasis on the expert having given evidence under cross-examination and 'preformed well' in so doing and whilst this can be an important factor it is not the only one. There is a body of opinion that says that the true experts are those who do the job day-in-day-out, not someone who is on the expert witness 'circuit'. Also, logically there must be a first time that anyone does something and so if previous experience of cross-examination is always the main factor for expert selection then one ends up with a very small pool of opinion.

Conclusion and judicial guidance

So what guidance can be provided to avoid some of the pitfalls of giving expert evidence outlined above? Whilst it will not directly apply to all dispute fora or jurisdictions, one could do worse than to act according to seven principles outlined in English case known as the Ikarian Reefer[1] which Creswell J stated as being:

"The duties and responsibilities of an expert witness in civil cases include the following:

1. Expert evidence presented to the court should be, and should be seen to be, the independent product of the expert uninfluenced as to form or content by the exigencies of litigation.
2. An expert witness should provide independent assistance to the court by way of objective, unbiased opinion in relation to matters within his expertise. An expert witness in the High Court should never assume the role advocate.
3. An expert witness should state the facts or assumptions upon which his opinion is based. He should not omit to consider material facts which could detract from his concluded opinion.
4. An expert witness should make it clear when a particular question or issue falls outside his expertise.
5. If an expert's opinion is not properly researched because he considers that insufficient data is available, then this must be stated with an indication that the opinion is no more than a provisional one. In cases where an expert witness, who has prepared a report, could not assert that the report contained the truth, the whole truth and nothing but the truth without some qualification, that qualification should be stated in the report.
6. If, after exchange of reports, an expert witness changes his view on a material matter having read the other side's expert's report or for any other reason, such change of view should be communicated (through the legal representatives) to the other side without delay and when appropriate the court.
7. Where expert evidence refers to photographs, plans, survey reports or other similar documents, these must be provided to the opposite party at the same time as the exchange of reports." T&T

REFERENCES

1. Case Reference [1993] 2 E.G.L.R. 183

Segmental success in detailed control

Technical journalist Maurice Jones examines some recent developments in improving both efficiency and quality of segmental linings

The selection of pre-cast segmental lining necessitates a high level of advance planning unlike, for example, various forms of sprayed concrete linings that can be adapted easily to the actual ground conditions found during excavation. The design of segmental linings will be highly influenced by site investigations and will be uniform for long stretches of tunnel. The selected design must be able to cope with any range of ground conditions likely within the tunnel, plus a factor of safety. Site investigation information will consequently offer input to the planning of any special segment manufacturing facility, or better allow a third-party supplier to schedule its production.

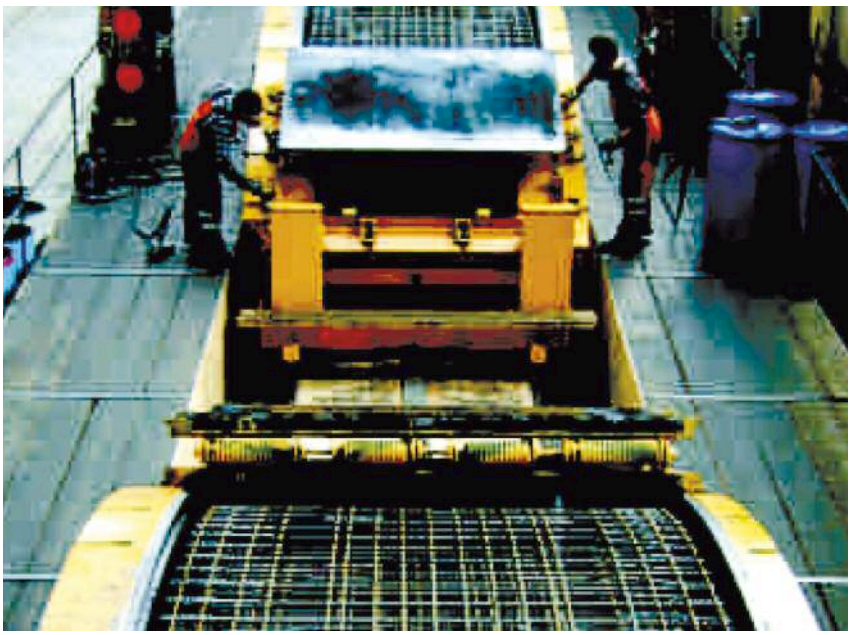
Pre-cast linings generally form a circular tube for convenience of installation within TBM shields and to better handle the loading, assisted by annular grouting.

Despite the limited design and functional flexibility of pre-cast segmental lining, with correct and careful planning and preparation, the system offers great potential for project success in terms of cost control and construction uniformity. From design to installation the whole process can be treated as an industrial manufacturing operation. Most possible snags in the production process must be anticipated and prevented, or costs due to project delays can be substantial.

At most stages the collection of data, its interpretation and feedback into the system are of great importance. Computer systems with dedicated software are invaluable for these duties once the process is correctly understood and the desired results decided upon. Their involvement range from computer-aided design of the lining and segment moulds, to installation instructions and monitoring integrated into the TBM overall control system.

Moulds & segments

Many projects involving facilities for the local production of lining segments are now led by manufacturers of the necessary segment moulds, whether they also fabricate the necessary concrete batching and delivery plant themselves or buy it in. The moulds are designed and manufactured with the aid of 2-D and 3-D CAD/CAM software to make the segments capable of forming a lining ring to the required tolerances.



Above: **Segment production for the Islisberg Tunnel, showing reinforcement cages in moulds supplied by Marti Technics**

CBE, for example, produces more than 1000 segment moulds a year for segmental lining rings of 3-15m diameter. As well as being designed by computer, they are checked for dimensional accuracy in three dimensions using laser tracker instrumentation.

Concrete batching plants used for pre-cast tunnel segment production mainly follow general civil engineering practice. One manufacturer in this sector has become an example of the rise of China's industry and economy as Milan-based CIFA was acquired by Zoomlion in September from the Magenta Fund. Changsha Zoomlion Heavy Industry Science & Technology Development Company is a leading construction equipment manufacturer in Asia. In tunnelling CIFA is known mainly for cast in situ formwork and concrete pumps as well as batching plants, but also supplies some segment moulds.

Specialist engineering designer and fabricator Marti Technics supplied segment moulds for the twin-bore Islisberg Tunnel on the Zurich Western By-pass. The moulds were used on Marti Tunnelling's existing carousel units at its workshops. Marti Technics supplied three sets of six moulds including the keystone formwork.

Reinforcement & fibres

Another important aspect of segment design and manufacture is the type and fabrication of reinforcement. Traditional rebar 'cages' can now be made automatically with steel rod cutting and bending machinery before placing in the segment moulds.

Fibre reinforcement is rapidly gaining in popularity, especially when combined with more traditional reinforcement. The original

function has been mainly to deter micro-cracking that can lead to bigger cracking and/or allow moisture into the concrete to corrode deeper-seated reinforcement. Perceived functional advantages have expanded in recent years and in some cases fibres can replace traditional reinforcement, with economic and production benefits. Materials costs have been an estimator's nightmare as the high prices for steel and polymers of only a year ago are dropping significantly. Whilst this may sound good news, the inherent current cost instability makes planning difficult. Some steel manufacturing capacity has been reduced and one fibre manufacturer reports a forecast of slight cost rises in steel during early 2009.

As described in a recent report from the UK Concrete Society (Technical Report 63 – 'Guidance for the design of steel-fibre-reinforced concrete'), the use of fibre reinforcement has enabled the number of segments in a designed lining ring to be reduced. While there are theoretical cost savings in not using reinforcement this results in other compromises such as the need for more segments to limit flexural stresses, including those caused during transport and handling. Excess stresses can also occur at segment joints or due to thruster rams, but these can be deterred by fibre reinforcement.

Steel fibres such as Bekaert's Dramix and Propex Novocon varieties are now well established for use in pre-cast segmental lining as well as sprayed concrete linings. Some of the high-tensile, cold-drawn wire fibres have special profiles for better anchoring, and can be galvanised to protect against water-based corrosion if deemed necessary. For easier handling Bekaert's Dramix fibres are supplied in lightly glued batches for break-up and dispersal during concrete mixing. A more recent high-tensile (at least 2000 N/mm^2) version of Dramix fibres suits concrete strength of greater than C50/60, have an aspect ration of 80, and can be used as shear reinforcement. High performance efficiency and lower doses required offer cost reductions.

The Propex Novocon range of steel fibres includes FE flat-end fibres and HE hooked-end for heavy-duty use in anchoring the fibres when in tension. The Duoloc range of steel reinforcement fibres are manufactured by IFT Fasertechnik in a patented process. IFT also supplies its own dosing equipment in the Dino range.

Thicker synthetic fibres can perform structural functions as an alternative to steel, but with different characteristics. Propex's HPP (High Performance Polymer) synthetic macro fibres are made from polypropylene. Elasto-Plastic Concrete (EPC)'s Barchip Shogun, Macro and Kyodo fibres are embossed throughout their length for better bonding with the concrete.

Other tunnelling uses for synthetic fibres such as Propex's Fibermesh and EPC's Barchip F are led by the need for fire protection, especially in transport and cable tunnels. The materials used are polymers and, for fire protection, are generally of fine monofilament diameter. On melting in a fire these create passages to relieve pore pressure. This has been shown to reduce the risk of concrete spalling.

Steel and 'synthetic' fibres are available in proprietary mixtures to offer a combination of optimum properties from both main types.

It is important that fibres are integrated into the concrete mix for pre-cast element production in a uniform way in correct quantities. Therefore metered dosing equipment is necessary. Such dosing equipment can be integrated into the controls of automated plant, providing increased productivity and quality.

Quality control

Many aspects of segment design and manufacture are specified by project consulting engineers, whilst it is widely recognised that other parameters have to be monitored, and, if possible, controlled in order to obtain best practice in segment manufacture and installation. All relevant Standards should be included in project specifications, but even if they are not, it is up to the segment manufacturer and contractor to comply with them.

In Europe the full list of construction Eurocodes were completed last year and will cause the withdrawal of any conflicting national Standards in EU member states from 2010. There is provision for including Nationally Determined Parameters on the basis of 'local' safety issues and there is a recognised need for further research into the use of certain materials and situations towards revised standardisation. Those standards including items of likely relevance to underground pre-cast segmental lining include Eurocode 2 – Design of concrete structures, Eurocode 4 – Design of composite steel and concrete structures and Eurocode 7 – Geotechnical design. Structural fire design is included in Parts 1-2 where relevant. In the UK further information is available through the new Eurocodes Expert website on www.eurocodes.co.uk or http://eurocodes.jrc.ec.europa.eu.

There are still no internationally recognised design codes dedicated to underground use, however, and procedures have to be based on available specialist research papers and guides as well as relevant parts of general construction codes and standards.

Monitoring and tests for values within design tolerances are commonly seen as the essence of quality control, but also essential is good practice to achieve the correct test results. Some of the activities that are crucial to product quality control are:

Good practice in manufacture:

1) Correct concrete mix batching within design tolerances and use with time limits of workability
2) Design and manufacture of moulds within design tolerances
3) Environmental conditions, or accelerated curing by steam ovens etc., within design limits for temperature, humidity, etc
4) Cleaning and oiling of moulds to ensure that no debris remains and demoulding takes place cleanly, to maintain the dimensional tolerances of the segments produced
5) Correct and careful demoulding, handling and stacking of segments (see 'Handing' below)

Testing:

1) Foreman checks on good practice during

Right: **Cleaning segment moulds at contractor Morgan Est's Ridham plant for the Croydon Cable Tunnel project**

Above: **Station for pouring concrete into Ceresola TLS moulds for the Hobson Bay sewer tunnel project**

manufacture
2) Monitoring of mould dimensions, preferably by high-capacity automatic system e.g. LaserTracker
3) Laser mensuration of produced sample segments (similar to above)
4) Test assembly of initial segment rings in factory to check design and correct assembly before problems on site
5) Structural testing of sample segments

Opinions vary on whose responsibility it is for dimensional quality control and what are acceptable tolerances, although there is a strong tendency to finer tolerances of even less than 1mm. Following the principles of industrial quality control it is apparent that all factors that could affect measurements should be taken into consideration that, in the case of pre-cast concrete, should include the stage of curing (and therefore shrinkage), ambient temperature, means of measurement, and what is actually being measured. In order to eliminate many variables, measurements should be taken at a fixed stage in the process sequence, and preferably under the more controlled conditions of a factory environment. Practically this stage should be between demoulding and fixing the gasket seal. In the case of segments a more comprehensive control of out-of-tolerance products may be obtained by measuring the production element i.e. the mould, rather than replying on sample measurements of the segments themselves. The latter would still serve as a check on sampled product quality although not as comprehensive as checking moulds.

Modern high-speed industrial instrumentation such as the Leica Laser Tracker and interferometer in this context is described in a paper – 'Modern high precision high-speed measurement of segments and moulds' - presented by VMT (Gesellschaft für Vermessungstechnik) staff to the 2006 ITA Congress in South Korea and other conferences that year. The software program TubGeo aids the evaluation of the many results to compare them with design values and tolerances.

Ram testing of sample concrete segments is carried out increasingly. In recent UK projects ram testing of Bekaert steel-fibre reinforced concrete segments has been carried out on the Docklands Light Railway (DLR) Woolwich extension, the Belfast sewer project and Croydon Cable Tunnel.

Segment handling

It is important to carry out careful handling and storage of segments during all stages from demoulding to ring erection at the TBM. In addition to any deficiencies in segment composition, poor handling is the greatest potential source of segment damage. As careful sequencing of segment delivery is usually practised, especially in curved drives, any loss of a segment due to damage can affect tunnelling progress disproportionally due to delays in tunnelling progress.

Correct handling is particularly important after casting when the segments will not be fully cured. Various devices have been developed, mainly by segment mould specialists, for steady lifting, linear transport and turning of the segments, sometimes combining more than one function.

In a recent project, the Hobson Bay sewer tunnel in Auckland, New Zealand, Ceresola TLS supplied specialist handling devices to Wilson Precast Construction of Papakura. These were part of an equipment list for a fully automated carousel line and moulds for the 3km-long drive.

Known mainly for its TBM back-up system but also now for many types of special equipment design and manufacture for underground use, Rowa produced two segment erection systems within hard-rock TBM back-up installations for Herrenknecht on the 10.75km long Wienerwald Tunnel. A major feature of the design is segmental lining rings of an exceptional 2.25m width to better match the performance of the TBM advance. The rings are erected without fasteners nor sealing and a cast in situ concrete sleeve applied inside to create an inner diameter of 9.65m from an excavation diameter of 10.6m. The back-up system incorporates many functions including the transport of in-situ concrete components and placement of the in-situ concrete, as well as pre-cast segment erection.

The construction of segments also has a bearing on their durability since there may be a tendency for corners to be removed or concrete to spall off reinforcement cages in the event of impact or other excess stress. Incomplete curing or poor composition would make this tendency worse. However, fibre reinforcement has been credited with minimising handling damage by making the segment structure tougher.

Installation

The use of trapezoidal designs of segments allows planned or correctional directional adjustments to be made by varying the positioning of the segments within the ring.

An important factor in successful installation is an appropriately designed gasket or seal between the segment joints. These are held in grooves around the perimeter of each segment and are made of various types of elastomer, depending on the application. They can be anchored in place as part of the segment casting process, or held in position with adhesive. Their function or functions can range from simply providing a cushion between segments to sealing against the ingress or egress of fluids and fines at certain pressures. They can be designed to tolerate an amount of lining movement due to ground pressure or tolerably inaccurate installation.

These functions are catered for by a wide variety of extruded profiles with different depths, widths and patterns of internal passages to allow compression whilst maintaining the seal. Advanced materials now used include hydrophilic polymers that expand in contact with water. Whilst these may create a better seal after a period in contact with water, they may not be so efficient in creating an effective seal soon after installation. For applications such as high groundwater pressure hydrophilic materials have been combined with more conventional compression seals such as in the Phoenix Evolution Seal.

Since its first tunnelling project in 1969, Phoenix has developed over 40 different

Left: **Fitting gaskets to segments at the Morgan Est Ridham plant**

cross-sections for more than 200 tunnelling projects. Sections are also custom-designed to specific design requirements

Daetwyler Rubber has been actively pursuing the current booming market in India for metro and water tunnels. The Delhi Metro Rail Corp (DMRC) has approved the use of its CoexSwell gaskets, which combine a conventional EPDM chambered seal with a hydrophilic profile. To gain approval all technical data has to be submitted in writing and afterwards explained in person. Thereafter the material has been cleared for use on subsequent projects.

Due to limited groundwater the lining being used in Delhi is designed for water pressures of 2-4 bar. The first metro in India to use Daetwyler products was line BC-18 including 6.4 km of underground route. The originally suggested standard segment joint profile 86-259 was replaced due to a high reaction force. Daetwyler developed a mono-EPDM seal with the maximum reaction force whilst successfully maintaining the required seal.

Right: **The VMT Lasertracker is capable of collection multi-point data in checking the dimensional accuracy of segment moulds**

Final check

Once the ring is placed, activities such as annular grouting and possible ground pressure on the ring take place. Excess distortion of the lining must be avoided to negate current and later problems with installations made within the tunnel.

In order to check on possible ring convergence the VMT Ring Convergence Measuring System (RCMS) uses a series of inclinometers in a network for data collection by continuous monitoring. Checks on vertical ring movement can be incorporated using a reference prism. Accuracy is less than a millimetre and results can be integrated into the TBM guidance system and controls.

Other systems from VMT useful for checking correct installation include the Grout Pressure Sensor System (GPSS) that enables events such as grout setting time, complete ring coverage and natural ground

pressure to be checked. In addition, the VMT GAPtrix replaces manual measurement and recording of tailskin clearance for input into the TBM Ring Management System. It employs a Leica DISTO with Bluetooth communication. T&T

Editorial index for Volume 40 2008

INDEX OF ARTICLES

SUPPLEMENTS

COMMENT

AUTHORS

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

www.coyles.co.uk/tunnelling

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UK & OVERSEAS OPPORTUNITIES

V- Engineering Recruitment

Current opportunities:

- **Principal Tunnelling Engineer** - Birmingham
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- **Geotechnical Engineers - Metro & Piling Projects** - Dubai, Singapore, Hong Kong
- **Senior Geotechnical Engineer** - Delhi India
- **Principal Tunnel Engineers** - Czech Republic, Hungary, Singapore & India
- **ITS Engineer - Tunnels** - Surrey
- **Construction Manager & Senior Tunnel Engineers - Water Project** - London
- **Senior & Section Engineers (Excavated & SCL Tunnel Exp.)** - Surrey
- **TBM Operators (Wirth machine Exp.)** - India
- **Immersed Tunnel Design Engineers** - Abu Dhabi, UAE or UK Based
- **Tunnels Project Directors** - Hong Kong & Surrey
- **Tunnel Engineers, Site & Design** - USA
- **Tunnel/Underground Structure Design Engineers** - UK, Australia, USA & UAE

Tel: **+ 44 (0) 207 754 5999** Email: **careers@v-engineeringrecruitment.com**
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Construction Managers - Required for Main Contractor for TBM drives and shaft sinking projects in **London & Sussex**. The right candidate must have a good tunnelling background.

Senior Engineers - Required for £40m 3m TBM tunnels both in **London & Sussex**.

Sift Engineers - Required for large bore tunnels and shaft sinking projects based in and around **London**.

Environmental Engineer - Required for Main Contractor to work on Tunnelling projects around **London**.

Mechanical Engineer - To work along side Senior Engineers on large TBM drives and shafting sinking projects in central **London**.

TBM Foreman - Based in **London & Sussex**. Experience in shaft sinking and large bore tunnelling projects is essential.

TBM Surveyors - Based in **London & Sussex**. Experience in monitoring and guiding TBMs is essential.

AXIS

Contact: Axis Recruitment (UK) Ltd
Tim Laite Tel: 01303 260048 Mob: 07766432531
tim@axisjobs.com

WEBSITE DIRECTORY

Dates & Events

12-14 FEBRUARY
RGMA-09
Varanasi, India
This International Symposium on Rock Mechanics and Geoenvironment in Mining and Allied Industries is being convened to assess and understand the interface of different aspects of the theory, tools and practices. Contact: Sanjay Kumar Sharma; tel: +91 9450 787 274; email: sksharma.min@itbhu.ac.in; web: http://www.itbhu.ac.in/min/conferences/

02-03 MARCH
Shotcrete for South Africa
Johannesburg, South Africa
Sponsored by the ITA, one of the themes of this conference is to the merits of introducing a nozzleman certification scheme in South Africa. Presentations will include a review of at least six different nozzleman accreditation schemes being used in other parts of the world. Contact: SAIMM; tel: +27 11 834 1273; email: raymond@saimm.co.za; web: http://www.saimm.co.za/events

11-12 MARCH
Multi-System Utility Tunnels (MUT)
Haifa, Israel
The first international conference in the developing field of design and construction of underground multi-system utility tunnels (MUTs) will present existing experience regarding planning and construction in Haifa and other towns worldwide. Contact: Diesenhaus Unitours; tel: +972 3 5651324; email: conven4@diesenhaus.com; web: http://www.multiutilitytunnels.com/

26-27 MARCH
China Tunnel Summit 2009
Beijing, China
The China Tunnel Summit aims to provide a platform for discussion of new tunneling technologies and challenges in a warm and professional atmosphere. This year's Summit will focus on Safety in Construction and Sustainable Development. Contact: Merisis; tel: +86 21 6247 8608; email: marketing@merisis-asia.com; web: http://www.merisis-asia.com/tunnel/

18-20 MAY
8th Iranian Conference on Tunneling and Underground Spaces
Tehran, Iran
"Underground Spaces for Safety, Better Environment and Energy" is the theme for this year's conference, which aims to offer a platform for exchange of knowledge and information on state of the art tunnelling development and practices. Contact: IRTA; tel: +98 21 886 304 95; email: info@irta.ir; web: http://www.irta.ir/conference2009/

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: http://www.wtc2009.org

07-10 JUNE
Shotcrete for underground support XI
Davos, Switzerland
Engineering Conferences International, in conjunction with the ITA, the Swiss Tunnelling Society and several other European Associations is sponsoring the Shotcrete for Underground Support XI. Bringing together specialists from around the world, state-of-the-art of shotcrete methods will be discussed. Contact: ECI; email: info@engconfintl.org; web: http://www.engconfintl.org/9as.html

14-17 JUNE
RETC 2009
Las Vegas, Nevada, USA
RETC is 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: http://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: http://www.straitcrossings.com

09-11 SEPTEMBER
IBTTA 77th Annual Meeting
Chicago, USA
The International Bridge, Tunnel and Turnpike Association's (IBTTA) 77th Annual Meeting and Exhibition will bring together more than 1000 toll agency professionals for 3 days of networking and innovations in toll industry. Contact: IBTTA: Tel: +1 202 659 4620; web: http://www.ibtta.org

13-16 SEPTEMBER
EURO:TUN 2009
Bochum, Germany
The 2nd International Conference on Computational Methods in Tunnelling is organised by the Institute for Structural Mechanics. Contact: Conference Secretariat: Tel: +49 234 32 29051; web: http://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

16-18 SEPTEMBER
Tunnel Construction and Underground Structures, Ljubljana, Slovenia
Slovenia's 9th International Conference on Tunnel Construction and Underground Structures is sponsored by the Slovenian Society for Underground Structures. Contact: SSUS: tel: +386 1470 4617; email: jakob.likar@ntf.uni-lj.si; web: www.drustvo-dpgk.si

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

BRITISH TUNNELLING SOCIETY

19 FEBRUARY: **Briars Lane Mine Stabilisation**
Members of the team discuss the specification, implementation and validation of chalk mine treatment methodologies. Presented by Chris Milne, Andrew O'Donovan and John Rigby-Jones.

19 MARCH: **Disputes in Tunnelling Contracts**
Speakers will consider the common causes of contractual disagreements on tunnelling schemes. Presented by Nigel Legge, Garry Crossley and Caroline Pope.

17-19 MARCH 2010
ISTSS 2010
Frankfurt, Germany
The 4th International Symposium on Tunnel Safety and Security. Manuscript abstracts should be submitted to the Secretariat by 01 June 2009, poster abstracts by the 01 October 2009. Contact: Anders Lönnermark, SP Technical Research Insitute of Sweden; tel: +46 10 516 56 91; email: anders.lonnermark@sp.se; web: http://www.sp.se/en/units/fire/news/ISTSS2010/

14-20 MAY
2010 ITA World Tunnel Congress, Vancouver, Canada
Prior to the 2010 Winter Olympics, the International Tunnelling Association (ITA) visits the spectacular city of Vancouver, British Columbia, for its yearly conference and exhibition. Contact: web: http://www.wtc2010.org

18-20 MAY
InterTunnel 2010
Turin, Italy
Tunnelling exhibition aimed at companies and suppliers involved in building and equipping tunnels and firms providing the systems and expertise for their safe and efficient operation. Contact: Mack Brooks Exhibitions; web: http://www.intertunnel.com

Contacts

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

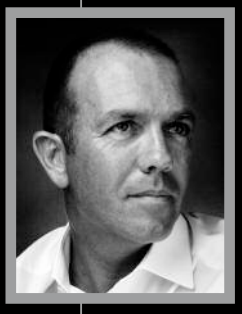
WEB
www.tunnelsonline.info

TEL
+44 20 8269 7789

FAX
+44 20 8269 7840

Tris Thomas

Amanda Foley



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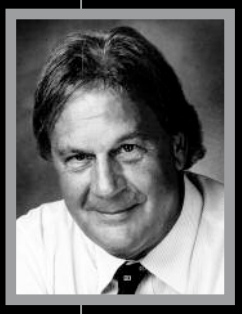

David Wildman

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: patrickjreynolds@hotmail.com

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

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