JULY 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON SCANDINAVIA

T&TI reports from Malmö's Citytunnel and plans for the Copenhagen metro

CAST IN-SITU LININGS

Case histories from the world of cast in-situ finial linings

Contents

FRONT COVER: Construction of the Eastlink road tunnel in Melbourne, Australia, which opened at the end of last month, five months ahead of schedule (p11).

WEB ADDRESS
www.tunnelsonline.info

CONVERSIONS
US$1.00
€0.63
£0.50

20

Cityringen is the next, entirely underground, phase of Copenhagen's metro system

40

The screw auger 'bone yard' at the Arrowhead tunnels, in the United States

FIRST BREAKTHROUGH FOR SHANGHAI GIANT.

The first of two of the world's largest tunnel boring machines, the S-317 Herrenknecht Mixshield (diameter 15,430mm), reached its target on May 21, 2008, six months ahead of schedule. The giant excavated the 7,472 meters of tunnelling for a three-lane road tunnel in only 20 months. The construction site team rendered excellent tunnelling performances of up to 144 meters a week. When tunnelling beneath the Yangtze river, the machine had to deal with a pressure of 6.5bar. The identical S-318, working on the parallel route, was able to match the performance of the S-317, achieving 6,500 meters of tunnel after 17 months.

The two road tunnels run beneath the Yangtze river from the Shanghai district of Pudong to Changxing island in the Yangtze delta and it is planned to open them for traffic on time for the 2010 World Exhibition in Shanghai. With the first successful breakthrough, this mega project is right on track to becoming a milestone in mechanized tunnelling. Herrenknecht congratulates the Shanghai Changjiang Tunnel & Bridge Construction Development Co. and the construction site team on this impressive success.

SHANGHAI | CHINA

PROJECT DATA	CONTRACTOR
S-317, S-318 **2x Mixshields** Diameter: 15,430mm each Driving power: 3,500kW each Tunnel length: 2x 7,472m Geology: sand, clay	Shanghai Changjiang Tunnel & Bridge Construction Development Co., Ltd.

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

Herrenknecht Shanghai Tunnelling Equipment Co., Ltd.
CN-2000131 Shanghai
Phone +86 21-58 48 33 03
Fax +86 21-58 48 61 99

www.herrenknecht.com

HERRENKNECHT Tunnelling Systems

Unforeseen... really?

An 'Act of God' is a legal term for "events outside of human control for which no one can be held responsible and which cannot be prevented".

We sometimes hear the expression banded around the tunnelling world following such misfortunes as a collapse. More frequently the old classic 'unforeseen ground conditions' is put in the frame, but in many ways they can be interpreted as meaning much the same thing, i.e. "it wasn't our fault, we couldn't have seen it coming so we couldn't have done anything about it!"

It's understandable in many ways, considering the levels of penalties involved in today's engineering climate, companies can be broken in such contractual situations. But it is also a rather unwise defence when looking at the bigger picture.

The truth is, this denial of accountability really isn't the way to make our industry look credible to the untrained observer, potential insurer, or inexperienced client.

We've read and researched numerous collapse reports here at *T&TI*, and frequently, although not exclusively, such events have been far from unforeseeable, whether it be anything from poor attention to monitoring information, to a lack of a robust design in the temporary works.

The truth is, when something goes wrong, an immediate and thorough investigation must be carried out, the reasons for the event catalogued for future reference, and if there is accountability, then unfortunately those in the spotlight should be made accountable. If such investigations do show that the events were unforeseeable and unavoidable then so be it, but this must not be used as a cover for possible lapses in good engineering practice.

Although this 'accountability' may sound harsh, obviously nobody wants accidents to happen, the reason we need to do this is simple.

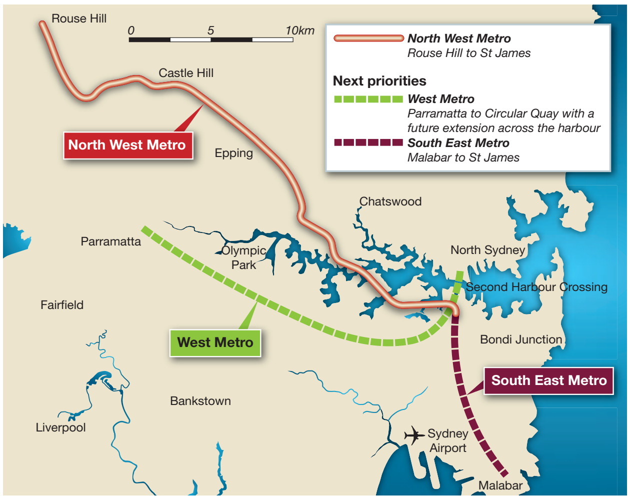
We cannot propagate the notion that in some situations we have little or even no control over what happens during tunnel construction, especially if the consequences are significant damage to property, or in the absolute worse case, the loss of life.

If the aviation industry blamed 'unforeseen air conditions' every time a plane crashed, it wouldn't be long before people would lose faith in flying. So why would we expect people to keep faith in an underground industry plagued by these so called 'unforeseen ground conditions'?

Tris Thomas

COMPANIES IN THIS ISSUE

Sydney plans mega-metro tunnels



Major metro developments are planned in Sydney

Site investigation tenders are being sought for Sydney's North West Metro project, part of Australia's largest ever transport infrastructure project.

The Aus$12.5bn (US$12.4bn) project, funded by the New South Wales Government, forms the first phase of the 'SydneyLink' initiative and is to include construction of a 32km long stretch of twin bore tunnels and 17 stations, running from Sydney's central business district to Rouse Hill.

Originally developed as the North West Rail Link (NWRL), a heavy rail line that was scheduled for completion in 2015, the decision to instead build the connection as a european-style metro line was announced in March by NSW Premier, Morris Iemma.

The North West Metro will be 38km long in total, following the previous NWRL alignment and having the same station locations. It will run underground from the city, beneath Victoria Road towards Top Ryde, and then via Epping to Castle Hill, Norwest and Rouse Hill. There will also be several key interchanges with the existing CityRail network.

The 32km long underground section will be built as twin-tube 5.5m diameter TBM bored tunnel, with the remaining 6km of the route being a combination of cut and cover, at grade or elevated.

The scheme is being developed by North West Metro project team, which incorporates specialists from a number of state agencies. Undertaking significant industry consultation, the team is currently tasked with producing a Product Definition Report, due for completion in November. The report will provide critical decisions on transport and land use strategy, procurement, design, operations, environmental approvals, delivery, timing and funding of the project.

Following this, registration of interest for the main civil and tunnelling works will be sought in the second quarter of 2009, with project planning approval and main package tenders due early autumn.

It is envisaged that the tunnelling and station excavation works will be split into a number of separate packages, with construction of the station boxes and tunnels commencing in 2010 at four major tunnelling sites. With such an ambitious schedule, the Government recognises that procurement and lead times of the TBMs required is a critical issue that needs further consideration.

The project will be completed in two phases, the first from Epping to Hills Centre by 2015, and the remainder by 2017.

SydneyLink also includes an extension to the M4 motorway, construction of the South West Rail Link, and possible metro lines to the west and southeast.

Road hole over Gautrain TBM

A leaking pipeline has been blamed for softening ground so much that a large hole opened in the road over the TBM excavating part of the Gautrain rail project in Johannesburg, forcing the shield to stop work for almost a week in early July.

Tunnelling work has resumed but the local authority's concerns over the condition of utilities has led to the introduction of a precautionary, three-phase programme of road closures ahead of the machine. Surrounding buildings are being monitored and have been stable, said contractor Bombela Civils JV.

The 6.68m diameter TBM was driving under Oxford Road at a depth of 12m, and had reached the section between North Road and 8th Avenue, when the road subsided in the early afternoon of 8 July. A hole up to 3m deep and 6m long by 4m wide first appeared, then it increased 12m long by 7m wide due to a fractured water supply pipeline.

Bombela said its preliminary investigation suggested that water seepage from the utilities above the tunnel alignment had weakened the soil, and led directly to the ground loss above the TBM, which was capable of, but not operating in EPB mode.

The contractor became aware of the problem underground when surplus material began to come in. The machine was switched to EPB mode.

Bombela, which is led by Bouygues, said repairs to the road were quickly completed but as a precautionary measure a series of phased road closures would be introduced as the TBM advanced.

The TBM (S-386) was manufactured by Herrenknecht to drive just over 2,820m from Rosebank towards Park station (*T&TI*, December 2007, p7).

In total, almost 16km of tunnel (excluding stations) is being excavated for the 77km long rail project.

Geology comprises mainly weathered granite with some silt, clay and boulders. There are several faults. Cover is 15m-80m and groundwater levels are at depths of at least 25m, Bombela said previously.

Hindhead drives ahead

Early excavation advances at the twin Hindhead tunnels in southeast England for the Highways Agency (HA) project to realign the A3 to remove a traffic bottleneck and help to protect the local environment at the Devil's Punch Bowl, a Site of Special Scientific Interest (SSSI). The horseshoe-shaped tubes are being cut through principally fractured sandstone with some clayey/silty fine sand, or more sand material, along the alignment which is above the water table. The 1.8km long drives are being constructed by SCL as elected during HA's early contractor involvement work with Balfour Beatty. The excavated width is 11.6m, giving a 96m^2 face area, and the finished width will be 10.6m. Groundbreaking was in February and the tunnels are to be open by 2011.

Robbins TBMs start on Delhi metro Ph2

Lowering and assembly of one of two Robbins EPBMs for Phase 2 of Delhi metro

Two Robbins EPBMs have begun drives on Phase 2 of Delhi metro from Jor Bagh station to Green Park.

The 6.52m diameter TBMs are to drive a pair of 2km long tunnels for half of the BC-16 contract section of the metro being developed by Delhi Metro Rail Corp (DMRC). The first machine was launched in mid-May, the second late last month.

Robbins supplied the machines, which were manufactured in Dalian, China, and employ a design by Mitsubishi Heavy Industries (MHI). The contractor on the section of the metro is a joint venture of Continental Engineering Corp (CEC), of Taiwan, and local form Soma Enterprise.

Lowering of the TBMs follows the slightly earlier arrival on the section of metro of a pair of 6.54m diameter Herrenknecht EPBMs (S-411, S-412). Also on the BC-16 contract, the TBMs are driving in the opposite direction.

Geology along the alignment comprises sandy silt, silty sand and gravels, and the groundwater will be up to 14m over the TBMs. The TBMs are designed to take 3 bar pressure. Cover to the tunnels is about 15m. The lining (5+1) has 1.2m long rings of 275mm thick segments, and two internal diameters will be used on the metro – 5.7m and 5.8m, respectively.

The JV contractor is also building four 318m long stations for the BC-16 section.

A total of 14 TBMs are to work on the metro expansion project as the client has a tight deadline to have the project completed before the Commonwealth games in the city, in 2010. Herrenknecht has a further two machines (S-403, S404) in the ground, launched at the end of 2007 by Metro Tunnelling Group (MTG) on contract BC-18 (*T&TI*, March, p8).

Robbins and Herrenknecht are active in other major tunnelling projects in India. For the Alimineti Madhava Reddy (AMR) scheme, Robbins is supplying a pair of 10m diameter double shields for a 43.5km long water tunnel. The company is also to supply another 10m double shield for a different water transfer tunnel, on the Pula Subbaiah Veligonda project – for which Herrenknecht has a 7.9m double shield (S-370) onsite.

Copenhagen moves metro ahead

Procurement plans for the next stage of Copenhagen's metro network are being prepared with a prequalification call due later this year for the 15km long, twin tunnel Cityringen project.

The next stage of the metro – Phase 4, the other having been completed over 2002-7 – will be built entirely underground. The Cityringen project also includes construction of 17 box stations to mostly standard design.

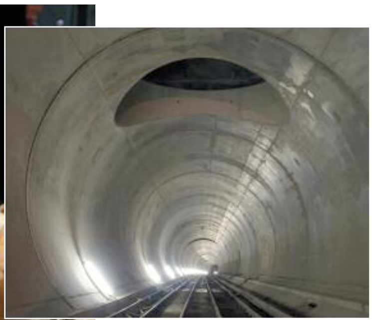
Civil works are to be undertaken in two or three packages of tunnels and stations construction. The client, Metroselskabet, is finalising plans for the packages. Tenders are to be called in mid-2009, contracts awarded in md-2010 and the entire project completed by 2018.

The client is also undertaking extra site investigation works over the next few months as there will be more saturated sand strata as well as the more familiar limestone encountered in the early phases of the metro development.

T&TI was told by Metroselskabet that four, possibly, five TBMs would be required for the project and that the client is considering taking more of the geological risk (see p20).

The client's consultant for the civil works is a joint venture of Cowi, Arup & Systra.

Gotthard advances on tracks, tunnels



Left: Contract signing for the trackwork package for Gotthard rail tunnel; Above: Tunnel lining and portal works make progress

Preparations to implement the recently signed trackwork and equipment contract for the Gotthard Tunnel project are getting underway as excavations and concrete lining works continue to make steady progress.

The US$1.5bn trackwork and equipment contract – the last big contract to be awarded on the 57km long twin bore rail project through the Swiss Alps – was awarded just over a year ago to the Transtec Gotthard Consortium.

The JV comprises Atel Installationstechnik, Alcatel-Lucent Schweiz, TRSS Thales Rail Signalling Solutions, Alpine-Bau, and Balfour Beatty Rail. It has appointed Pöyry to provide engineering services under a US$15.8M contract.

By the beginning of this month, just over 113km or 73.8% of the tunnels, galleries and passages on the Gotthard project had been excavated. Last month, almost 1.7km was opened in total. In terms of lining, two-thirds of the excavations have had inverts constructed and 42%, or 47.6km, their vaults.

On the Erstfeld section of the project, twin 9.58m diameter Herrenknecht TBMs are getting underway on 7.7km drives. A different pair of the manufacturer's shields, of 9.43m diameter, are pushing through the Faido section. The pairs had previously bored the Amsteg and Bodio sections, respectively (*T&TI*, June, p10).

A year ago the award of the trackwork and equipment contract was disputed by rival bidder, Swiss Railway Infrastructure Consortium Gotthard (SBK). The JV comprises Implenia Bau, Sersa Group Management, Rhomberg Bahntechnik, Siemens Schweiz, Murer-Strabag and Walo Bertschinger.

Concerns over potential delays put the entire construction programme at risk of achieving the opening deadline of late 2017. An out-of-court settlement was reached between SBK and the client, AlpTransit Gotthard Ltd (ATG), at the end of 2007. The client agreed to pay SBK a one-off sum to reimburse tender costs (*T&TI*, February, p11). Separately, SBK entered into a deal with Transtec.

The implementation plan for the project will see work start at the Biasca installation site. It is proposed that installation of the rail infrastructure begins in the tunnels through the south portal in the second half of 2009. Fit-out through the north portal is planned for the end of 2011. In addition, the contract requires a further 11km of installation to join the tunnel to the existing rail network.

Shannon set for immersed tube

Above: Concreting works underway for the immersed tube tunnel near Limerick, Ireland, to cross the river Shannon

Concreting works are well advanced in the drydock near Limerick, Ireland, for the immersed tube tunnel that will cross the river Shannon as part of the ring road being built around the city and will tie into the M7 motorway.

The Strabag International-led joint venture building the road plans to complete construction of the public-private partnership (PPP) project in just over two years. It is preparing the immersed tube elements in a 600m long by 33m wide drydock on the north shore of the river.

In total, including entrances and ramps, the tunnel section is 915m long. Strabag is itself undertaking the tunnel construction. The tunnel will be built using five elements, each 100m long.

The tunnel is 22.7m wide at the top and 8.5m high. At the base, the slab is 25m wide and 1.15m thick. The structure holds two cells, each approximately 10m wide by 6.1m high.

The contractor is using two Peri formwork carriages to cast each element in a 20m long sections working in a six day cycle. The walls and slabs are concreted in a single pour, and the concrete is cured using internal tubes over three to four days. Rebar cover is 60mm-80mm. The stopend formwork holds waterstops for the casting joints between the sections.

With a lifespan of 120 years, the 20,000 tonne elements will be floated out of the drydock and placed in a prepared channel in the riverbed.

On the opposite bank of the river a cut and cover tunnel is also being constructed.

The JV building the Limerick Southern Ring Road is DirectRoute (Limerick) Construction, and in addition to Strabag it comprises John Sisk, Lagan Construction and Roadbridge.

Seli set for NY ESA branch run

The Seli TBM on New York's East Side Access (ESA) project completed its first drive of a bifurcated tunnel last month and is being returned for relaunch to bore the lower branch.

Seli's 6.7m diameter double shield – a refurbished Robbins original – was launched in late September 2007 with a preliminary configuration from a cavern below 63rd Street and 2nd Avenue. The final configuration was in place by early November.

A twin, bifurcated tunnel is being bored by a 6.7m variable diameter Robbins main beam TBM, which was launched less than three months after the first machine – shortly after the Seli machine had advanced over 200m and reached its final configuration. It will follow a similar sequence of excavation.

Both TBMs had to be brought from Queens on the other side of the East river through an immersed tube tunnel to their launch boxes.

Seli commented that while there was a common expectation of the second TBM being the faster to assemble, both machines took similar times. As such, the shorter delivery time for the refurbished machine has translated into it being launched about two months prior, and the machines have maintained steady progress.

Geology along the alignment comprises schist and gneiss of UCS 80MPa-200MPa. Lining is cast insitu concrete for the worst parts, and elsewhere ribs, mesh and bolts. More support has been needed than predicted for both first drives though cutter consumption in the abrasive schist is less (*T&TNA*, March, p12). In total, each machine is to drive approximately 3.85km in two runs.

The Italian firm, a subcontractor to the Dragados/Judlau joint venture, said average advance rates have been substantially the same when taking into account standby time for its machine when grouting, probing and draining.

Robbins said its main beam TBM has averaged 11.1m per day and reported that the Seli double shield averaged 9.8m per day. By early July, after the Seli shield had ended its first run, the Robbins' main beam shield had driven 1.4km, or just over half, of its parallel 2.6km bore.

The grouting, probing and draining works have benefited both TBMs, added Seli. However, when deducted its shield performed 20% faster, it claimed.

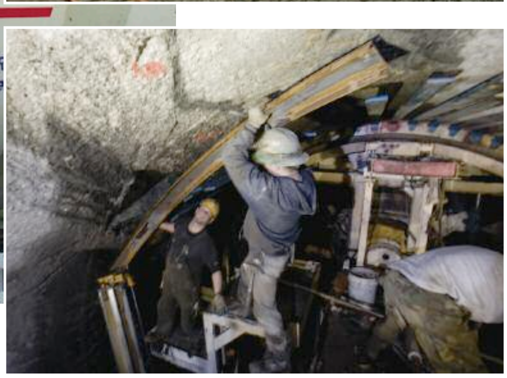
In addition to difficult ground, the progress of the first drives is affected by being only 1.5m apart, which provides for only minimal tunnel support. The gripper and thrust pressure have been halved to stay within safe limits, said Robbins' field service manager King Daniels.

Seli's shield, built for disassembly and transport through the tunnel by having a 'self-collapsing' set-up of retractable shield cans, is being walked back along the tube to the chainage from were it is to be relaunched on the branch tunnel drive.

The Robbins shield's variable diameter – enabled by unbolting four cutterhead sections, using hydraulically-positioned supports for its front, side and roof, and also collapsing the front shoe – will enable it to retreat for relaunch. The diameter can be reduced to 6.1m.

The project is being undertaken by Dragados/Judlau on a US$428M contract (CM009) with Capital Construction Co of the Metropolitan Transportation Authority (MTACC). The ESA project is part of the Long Island Rail Road (LIRR) scheme.

Late last year, as the machines were getting underway, the anticipated times for the turnarounds was about May for the Seli shield and mid-year for the Robbins TBM.



The Seli's TBM (above) and the Robbins machine (right) are making good progress on their first, parallel drives on New York's East Side Access (ESA) project

Eastlink opens in Melbourne…

The Eastlink road and tunnel opened at the end of last month in Melbourne – five months early – and recorded 275,364 average daily trips in its first seven continuous days of operation.

Eastlink has twin 1.6km long, three-lane tunnels under Donvale's Mullum Mullum Valley, and were excavated up to 53m below the ground surface. The tunnels are connected every 120m by cross passages, and there are 14 in total.

The tunnel was built under a design-build contract, valued at approximately Aus$400m (US$390M), by a joint venture of Thiess and John Holland.

Five roadheaders were used, each of the four principal Voest Alpine ATM 105 ICUTROC units excavating from portals and the last in the lower half of the tunnels. Some drill and blast work was also employed on the tunnelling phase between August 2005 and March 2007.

A total of 440,000m^3 of rock and earth were excavated in total – just over two-thirds by October 2006, by when 11 cross passages had also been opened.

Waterproofing and tunnel lining ran from August 2006 to last September with membranes applied throughout, and then pre-cast segments were placed on the invert and cast insitu concrete poured in 16m sections along the length of the tubes for the arches. The lining work involved approximately 50,000m^3 of concrete. The roadbase was formed by crushed and recycled spoil from the excavations.

The entire 39km long Eastlink project has a total cost of Aus$2.5bn (US$2.45bn). It is owned and operated by ConnectEast Group, which comprises two management investment schemes that in turn hold ConnectEast Management Ltd, a wholly-owned subsidiary of the Macquarie Group.

The project funding also includes Aus$260M (US$254M) of equity contribution, or almost 27%, by the Thiess and John Holland Infrastructure Trusts.

The contractors and Macquarie have also recently been named for the Brisbane Airport Link (p12).

… as Lovat supplies sewer TBM, pushes Coslada

John Holland has ordered an EPBM from Lovat for a sewer contract in Melbourne and the Canadian TBM manufacturer also reports that another shield has completed about three-quarters of the first leg of a larger sewer in Coslada, Spain.

Lovat is to supply John Holland with a 2.92m diameter mixed face EPBM for a 2,088m long sewer entirely below groundwater. The head over the invert level is 9m-11m, and the depth of cover over the crown is 8m-12m.

Geology along the route comprises the Yarra Delta Group, which typically comprises a range of marine and estuarine sedimentary deposits – sand, silt, clay – and may also include some basalt.

The machine (RME115SE) will be equipped with a four-spoke, chromium carbide-plated cuttinghead fitted with backloading rippers, which are interchangeable with 15.5" disc cutters. In addition, the shield will have a two-stage, two chamber integral airlock. It is to be delivered early next year for the Melbourne Main Sewer Replacement project.

In Spain, the manufacturer reports that on the Coslada sewer project its refurbished 4.7m diameter EPBM has bored more than 70% of the 2,250m long first section of tunnel. Lovat said breakthrough is expected by late September.

Best rates achieved for a day, week and month were 32 rings, 122 rings and 336 rings, respectively, said Lovat. The TBM was launched in February. The contractor is working two-11 hour shifts on weekdays. Sando said the average progress rate is 21.2m per day and the tunnel depth is 23m.

The second, and final, bore for the RMW185SE Series 20202 machine is 1.4km long.

Geology along the first drive comprises mixes of highly plastic clays and gypsum with each other and, separately, with water. The ground along the second drive comprises silty sand and fractured gypsum.

The project is part of the development of the El Canaveral housing project, one of the largest in Spain, according to Sando.

Next design phase for Helsinki airport tunnels

A joint venture led by Pöyry has been awarded the detailed design contract by the Finnish Rail Administration (RHK) for the twin tunnels on the new link to Helsinki-Vintaa airport.

The JV was awarded a Euro10.6M (US$16.9M) contract, almost three-quarters of which goes to Pöyry, to take forward the initial design work done last year on the underground stretch of the project (*T&TI*, August 2007, p7). The contract is to be formally signed next month.

As initially planned, each single-track rail tunnel will be 8km long and is to be excavated under the airport area. The route will also have three or four underground stations, and last time there was no indication of the number.

Previously, it was said that the tubes would be driven by drill and blast and construction was anticipated to start in 2009 for completion around 2010-2011. There has been no further information on the programme but the consultant JV is hired to 2012.

The entire rail link between Martinlaasko and the airport will be 18km long, as first planned, and linked to the Kerava and Leppavaara lines. The link will allow travel between the capital and airport in 30 minutes, and trains are to run at 10 minute intervals. Funding will be from a mix of state and local sources.

The studies last year were undertaken in a US$1.5M contract by Pöyry working in partnership with WSP Finland. They worked together on earlier planning of the scheme.

BrisConnections picked for airport link

The preferred bidder for the Brisbane airport link, involving a 5.25km long toll tunnel, is BrisConnections.

Under the contract, the consortium will design, build, finance, own and operate the link. Tunnelling between Bowen Hills and Toombul will involve combinations of shield, roadheader and cut and cover, to result in a total of almost 11.8km of underground ramps and tunnels.

Queensland state government awarded the contract to the consortium, which comprises Macquarie Capital Group, Thiess, John Holland, Arup and PB.

A joint venture of Thiess and John Holland is to undertake the design and construction of the link under a fixed-price, fixed term contract for completion by 2012.

The JV plans to use two TBMs at the Toombul section to drive south, and 11 roadheaders elsewhere.

Spoil from the TBMs will be removed by conveyor to the Brisbane Airport Corp fill site. Roadheaders and two Herrenknecht TBMs are presently being used on the North-South link in the city (p25).

Operation and maintenance is to be undertaken by a separate JV of Thiess Services and John Holland Services. The contract will be fixed-price for an initial five-year term.

The airport link project is part of Brisbane City Council's TransApex plan, and will operate as a 6.7km long electronic toll road. The scheme should cut travel time to the airport – 17 minutes by 2012, and 47 minutes by 2022.

The state government said the airport link will cost Aus$3.4bn (US$3.3bn) but the concession financing package means taxpayers will only have to contribute Aus$47M (US$46M).

The contract package also involves construction of a 3km long road (half in tunnel) between Windsor and Kedron on the Northern Busway, and a 750m long bridge at the airport.

BrisConnections is funding the project with debt and equity, and in addition to contributions from consortium members it is proposed to have an underwritten share offer later this year.

The finance package has been put together by Macquarie Capital.

In total, the three projects are expected to cost Aus$4.8bn (US$4.7bn), including land, and Aus$4bn (US$3.9bn) excluding land. The government will contribute a total of Aus$1.5bn (US$1.47bn) – less than two-thirds of that expected.

Abu Dhabi sewer prequal call

The deadline for prequalification submissions for the new Abu Dhabi sewer tunnel scheme - the Strategic Tunnel Enhancement Programme (Step), which involves approximately 80km of deep excavation and link sewers - is the end of August 2008.

Step comprises 40km of deep sewer tunnel of 3.5m i.d. – 5.5m i.d., to be driven by TBM. A secondary corrosion protection lining is to be installed on completion of the tunnel build. The scheme also includes approximately 40km of link sewers of up to 3m i.d. to be constructed mainly by pipejacking.

Geology along the route comprises weak sandstones, siltstones, mudstones and gypsum. It is expected that up to eight pressurised face TBMs will be employed on the scheme.

Tender documents for three design-build contracts for the deep sewers, and two design-build contracts for the link sewers, are to be issued from about late September to December. There will also be a single design-build contract for two $30m^3/s$ capacity pumping stations.

The programme manager, CH2M Hill, expects the contracts to be awarded over January-April 2009.

Construction of Step is to be completed by the end of 2012 for the client, Abu Dhabi Drainage Service Co.

Bickhardt job near Bad Sackingen

Bickhardt Bau has won a contract for a 400m road tunnel as part of the construction works on the A98 Murg-Hauenstein section near Bad Sackingen, Germany.

The company beat off six other bidders to win the Euro10.7M (US$17.1M) contract including VAT at 19%. In assessing the tenders, the client gave a 90% weighting to price and 10% to technical content.

Bids were more than estimated. Excluding tax, the contract value is Euro9M (US$14.4M), which is almost 6% higher than estimated by the local authority client Regierungspraesidium Freiburg.

The contractor is to build a 9.5m wide by 5m high road tunnel. The structure is being constructed by a 12.4m wide excavation below a ground slab, and is scheduled for completion in March 2010.

PB's Monsees wins lifetime award

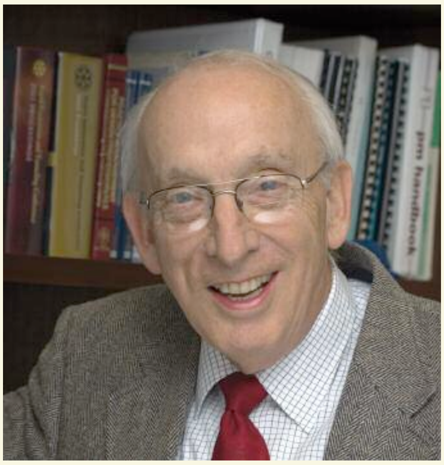
Jim Monsees, senior VP with Parsons Brinckerhoff, has seen been given a lifetime achievement award by the Underground Construction Association (UCA) of SME for his work on US tunnels, geotechnical investigations and design, and underground structures.

His responsibilities with PB include technical director on projects involving transport and water tunnels, underground storage of nuclear waste and studies on protective buried structures. In particular, Monsees developed new technical approaches to seismic design of underground structures.

The projects range from East Side Access and N-Line metro extension projects in New York, the deep tunnel sewer system in Hong Kong and LA's Sepulveda tunnel widening to sewer and light rail projects in Portland, the Central Artery/Tunnel project in Boston and the City Link tunnels in Melbourne. For many of the projects as well as tunnels in Mexico City, he has had significant involved in specification for soft ground excavation by EPBMs.

Additionally, projects he has worked on include: LA's Red Line Metro where he was chief tunnel engineer; the superconducting super collider in Texas where he was tunnel design manager and chief underground engineer; the Santa Ana River Wash tunnel in California for which he acted as design project manager; and, he was also department manager of underground engineering for the nuclear water repository in Tuff, Nevada.

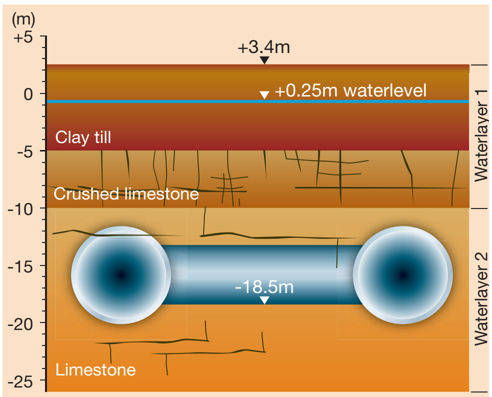
He has served on tunnelling committees of the National Academy of Engineering, the American Society of Civil Engineers (ASCE) and the Underground Technology Research Council, and was a founding director of the American Rock Mechanics Association.




BORING
through FUTURE
COPISA
SELI
FCC CONSTRUCCION
COPISA
UTE TUNEL SANT JUST
SELI
TBM Systems Manufacturers & Tunnel Builders
SELI is today the only global tunnelling Company, with over 600 Km of tunnel projects in all continents and able to cover the full range of market demands:
TBM systems manufacture
Tunnel Builders
TBM systems overhauling and rental
TBM operation services and supervision
Rolling stock
Segment moulds
SELI
www.selitunnel.com - www.selitecnologie.com

Forging links in Malmo

Above: Fig 1 - Malmo's Citytunnel project will help the city benefit more from the Øresund Crossing
Below: Fig 2 - Twin tunnels were bored in limestone



Construction of the Citytunnel project in Malmö has called for twin fast-track TBM bores, a fresh approach to lining and cross passages, and a strong emphasis on co-operation. Report by contributing Editor, Patrick Reynolds

While the sponsors and builders of many construction schemes generally look for the gains that positive, operational relationships can bring to themselves, and sometimes each other, the core team planning the Citytunnel project in Malmö had an edge; they'd done it before, and successfully, on the Øresund Crossing.

The Citytunnel project will hook into the Swedish end of the Øresund link before the end of 2010 – slightly ahead of schedule as announced early this month. The project has enjoyed accelerated progress due to the co-operative, lean project management approach, supported by a thorough risk management system, and a firm focus on production – most especially on the main works to date; the design and build contract (E201) for the tunnels.

By all accounts the co-operative approach, brought to Malmö by some of the key players on the bridge works at Øresund, has worked well on the tunnelling contract and the rest of the project. A case was made to the national rail company, Banverket – the biggest investor in the project – to employ the co-operative approach; it was put by Örjan Larsson, a key manager on the Øresund link. He sought, and was granted, the necessary autonomy and became project manager of the Banverket subsidiary that would deliver the scheme, Citytunneln, in 2001 - shortly after Øresund opened.

The budget for the entire scheme has been consistently given in local, 2001 currencies – i.e. SKr9.45bn (2001 currencies, equivalent then to US$1.3bn). The figure is the net present value of the costs of the project, discounted back to the base year of 2001. Banverket is providing 72% of the funds for the scheme, which will establish a 14km long fast-link from Malmö Central station, or Malmö C, to the Øresund Crossing plus some additional rail connections.

Planning got underway in earnest in 2002 and before bids were called the following year there was a strong message issued that co-operation on this job was not only wanted but expected, demanded. The value placed on it was "very high", says Michael Myhré, the client's project manager for tunnels and who had come from the Södra Länken 03 job, in Stockholm, and prior to that led YIT Sverige. As such, it would be a key criterion in assessing tenders.

After contracts are issued, though, like anything else, what you get is up to the people involved. In this case that would mean having people on each side who believed in the value of co-operation, of not blaming, of striving daily to develop, support and, indeed, embody such a living culture. Myhré notes that such an approach is not simple to produce and nor does it come from a slight adjustment in method or manner for most people, not least those in construction.

A JV of Bilfinger Berger (50%), Per Aarsleff (25%) and E Pihl & Søn (25%) – the Malmö Citytunnel Group (MCG) – was awarded a 52-month tunnelling contract to build the running tunnels, cross passages and a cavern for Triangeln station. The contract was valued at just under SKr2.3bn (December 2003 prices), and is structured as a lump sum offer with milestone payments. The tunnelling job was awarded in late 2004, work started in April 2005 and is due for completion by August next year.

The client and contractor note that, following the award and mobilisation, it took a year for Larsson's co-operative approach to filter down, and only did so by the example of the leaders on each side. Myhré says: "It is a big step to dare to be open."

In large part it is about trust, adds Henrik Christensen, the client's technical manager who was design manager on Øresund. It starts at the leadership levels, he says, through word – language, words, communication – and deed – delivering what was said and do so on time, or early. People get chances and if the effort is not made, daily, then it taints or even damages potential trust and openness, he believes. That approach, in openness with standards, had to start with the leaders and be consistent, maintained, and only by such prolonged example would others come to know it was for real, and act more openly themselves.

It is not about taking a management philosophy out for a spin. Rather, it is a foundation to systematically get practical results, to spotlight production, as on the Øresund Crossing.

For example, at Malmö, the open relationship approach enabled both TBMs to start up early at the launch site in Holma, Myhré notes. With two concrete box tunnels in the shallow, 360m long cutting which was experiencing more groundwater inflows than anticipated, it was agreed - with the client keen to see both drives start as early as possible - not to close them but let the supply trains cross-over through openings to support getting the shields underway. Therefore, compared to the schedule in the bid the TBMs were both launched two months early.

Johannes Truschel, managing director of MCG, says: "We kept the focus on the top people co-operating upfront."

Tunnelling challenge

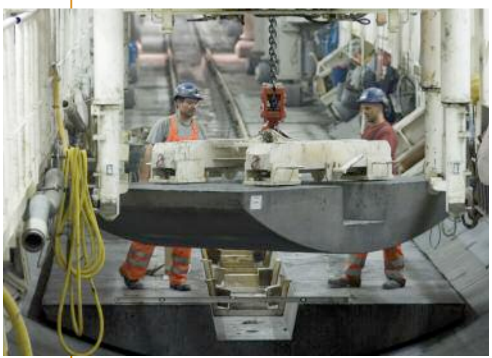
With production the focus, the JV's challenge was to concurrently build twin 7.9m i.d. running tunnels from Holma, breakthrough and relaunch at the Triangeln station cavern just over half way along the northbound route, and finish in Malmö C (figure 1). In total, each 8.89m diameter Herrenknecht EPBM would complete two runs that total approximately 4.6km.

Geology along the alignment comprises 4m-10m of clay till (moraine) over a 60m thick layer of limestone through which the tunnels would be excavated. The till is poorly graded, overconsolidated silt with sand, gravel and cobbles interbedded with sandy and gravely layers (figure 2).

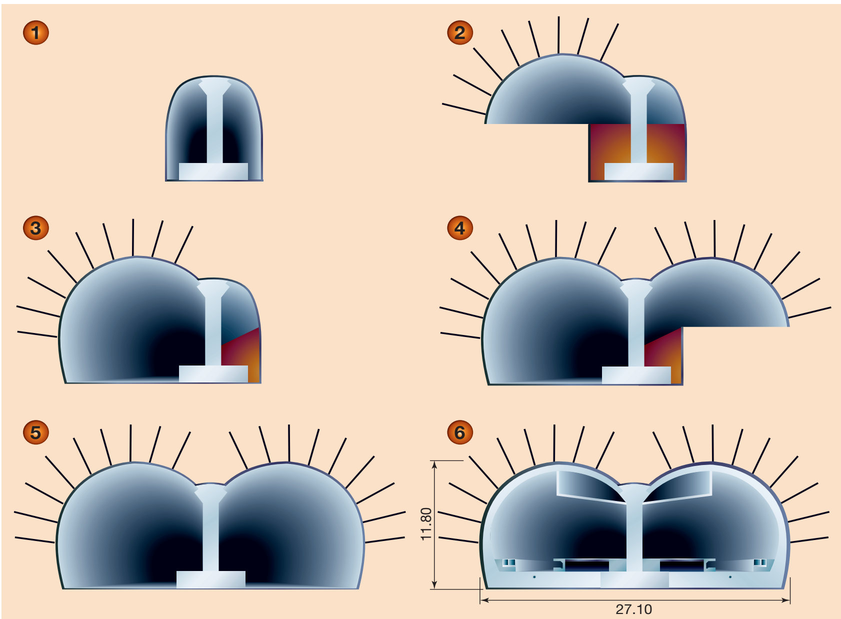
There are three zones of limestone:

- Top, Copenhagen limestone, which has high silica content, significant quantities of flint. Up to 8m thick, it is often cracked and therefore highly pervious
- Middle, the Transitional Unit, is 2m thick with slightly indurated marl
- Lower, Bryozoan limestone is non-homogeneous with high content of fossils, and extends to depths of 50m-60m. Less pervious than Copenhagen, its upper layer is usually cracked and pervious. North of Triangeln station the rock is slightly more pervious in a region with much surface water

The groundwater is in two distinct zones but connections are expected due to local fissures in the north. The upper zone is within, and over the till and has high hydraulic conductivity. The second aquifer is entirely within the Bryozoan limestone



Below: **Fig 3 - Triangeln station cavern was built by a central tunnel with permanent pillars, partly backfilled to enable the adjacent tunnels to be opened by heading and bench, then all three were joined** Left: **A TBM is pulled through the cavern**



and hydraulic conductivity is far less. The primary challenge for tunnelling works, therefore, is at the northern cross passages. Overall, along the main tunnel alignment the water table varies 1m-7m below ground surface.

MCG worked closely with the manufacturer to build the EPBMs on a part new/part refurbished basis. New components included the main parts – cutting head, tools, main bearings and screws. This procurement approach cut down potential manufacturing time as a further aspect of the focus on production, and so contributed also to the shields launching early.

The twin EPBMs were S-340 (‘Anna’) and S-341 (‘Katrin’). They had cutterhead power of 2,400kW and torque of 11,785kNm. Anna bored the west side tunnel and was launched on its first, 2.7km long drive in November 2006. Katrin began to bore the east side tunnel in January 2007. Given the groundwater levels, the shields worked steadily in EPB mode. The tunnels run 20m-25m deep to invert level and external walls are 10m-30m apart.

Excavation began with six-day weeks with two, 10-hour shifts (ending midnight). As work progressed, MCG got more crew and progressively stepped-up to round-the-clock operations over six, then seven days – again, with the changes, and cost, supported by the client. Production rates improved steadily and operations of the shields also benefited from exchange of shift engineers and foremen.

In August and September last year, respectively, the TBMs holed through at the open box next to Triangeln cavern. They were pulled through, underwent maintenance and refurbishment, and were relaunched from the open box at the other side in November and December, respectively. Ground conditions experienced were much as expected, MCG says. Technical manager for the TBM works, Frank Abel, adds that the fines proved generally more abrasive than estimated. There were only slightly more maintenance interventions than planned, and the shields were designed to replace tools from behind the cutterhead.

The shields did hit one band of particularly hard limestone, coming on it suddenly in only 1-2 advances and the EPB plug showed a significant drop-off in fines. Fortunately, the reduction was not enough to disrupt the plug but a back-up pump was ready to fit to the screw and take off excess water, should the need have arisen.

The TBMs were supplied by Schöma locos and Mühlhauser wagons. Mucking out was by high-level, wall-mounted

Right, and above: **Rings had flat-faced edges. The joints helped to ease segment removal at cross passages, where special segments also formed ‘diamond dowels’ for stress distribution and so avoid the needs for framing**

continuous conveyors, supplied by H+E, with maximum lengths of 5.7km. The spoil was transported from Holma to Norra Hamnen for disposal in a settling lagoon. Tunnel ventilation was by blowing.

The EPBMs completed their final, 1.9km long drives in March and April this year, were quickly dismantled at Malmö C and having been contracted with a buy-back option were sold back to Herrenknecht, said MCG.

In total, Anna excavated 4,626m and built 2,570 rings, and Katrin bored 4,594m and erected 2,552 rings. Planned progress was 15m/day and as crews and working time were increased the best rates achieved were 22 rings (39.6m) in 24 hours and 113 rings (203.4m) in a week. The TBM crews built on the programme lead won at the outset and finished approximately three months early against initial plans.

Segments & cross passages

With the client’s approval, the JV contractor used different approaches to both join the segmental rings and prepare them for cross passage construction.

From the outset, the contractor aimed not to have plywood packing and male-female joints between the rings, a quite different approach to Bilfinger Berger’s hometurf in Germany. In its technical discussions with the client at the tender stage the proposal was made to have, instead, flat concrete edges. The benefit

Above: **The TBMs finished their twin drives in March and April**

would be to allow the gasketed rings – (7+1) segments forming 1.8m long, 42 tonne rings – to face directly onto one another, except for the gaskets. A similar method has been used in Toulouse, France, and the client was open-minded about the possibilities for Malmö.

More than 80 segments were produced daily from the plant (single carousel, six sets of moulds). Each 350mm thick segment was designed for a 120-year life and is able to withstand temperatures of up to 1300°C in fires for three hours, helped by PP fibres in the concrete mix to help reduce explosive spalling. The approach was similar to requirements on the Øresund immersed tube tunnel.

The flat-faced rings also eased construction of the cross passages by allowing segment removal without adjacent ring movement. Coupled with a new stress redistribution system using modified segments, the flat-faced rings allowed cross passage openings to be formed without the need for steel bracing or other additional framing. A patent has been applied for the stress distribution system.

For the system, segments are modified in their edge detail during manufacture - specifically, V-cuts are formed which, when married to neighbours, form diamond-shaped holes in the erected rings. During construction there are short steel box sections inserted in the rakes of holes and cemented into place - like dowels, in effect.

At Malmö, the cross passage openings are three rings long. There are 24 'diamonds' above the position, in rakes of six up each of

Below: **The 7.9m i.d. lining was built with seven segments and a key**

the four affected ring joints, and also 24 below, hidden under the permanent invert. Each band of diamonds acts like a lintel, redistributing the compressive ring load laterally to the adjacent, complete, normal rings. The applicability of the combined flat-face and diamond dowel system depends, of course, on the strength of the bedrock.

The benefits from the system include reduced construction time and cost, says MCG, and securing such gains requires careful segment manufacture and co-ordination of their logistical delivery and placement against TBM progress.

Prior to mining the cross passages, grout curtains were injected ahead of a number of locations. The face was probed 6m-8m ahead and advanced in 1m steps, progressing by single-line working operations from a stretch of totally dedicated track in each running tunnel once the TBM trains had passed. After placement of waterproofing and the lining, a reinforced concrete frame is poured to complete the portals. In total, 12 cross passages are being built in the bored tunnels, each 3.8m i.d. and varying between 12m-30m in length. When the drives were over 10 cross passages were built, the last will be next month.

The other main underground construction work to finish is the cast insitu lining for the 280m long cavern at Triangeln station (figure 3), which was opened by a series of heading and bench excavations in what were drifts, in effect (*T&TI*, March 2007, p18-21). Placement of the cast insitu, 500mm thick final lining should be finished by year end, about a year and a half after the cavern, which is propped by 29 permanent concrete pillars down the centre, was opened to receive the TBMs.

Risk, production and project management

Risk management has been a key aspect of project management, which has helped the focus on production. There is a leanness to the system at Malmö; traditional levels of constant consultant and lawyer inputs were trimmed, and those smaller gatherings between the client and the respective contractors operate in a framework of separate meetings to determine technical and financial matters. As such, effective co-operation between the client and contractor was crucial.

The client wanted a formal separation of the two intimate aspects of work – technical and financial. It wanted the best reasonable technical solution to be pursued, and without top-down diktat so answers could develop from the ground up, from engineers growing into the co-operative environment.

As ideas were developed, or refined, they came to the client's technical support unit, under Christensen, which works across the entire project and is staffed by many with Øresund experience. The unit has a watchdog role, but no veto – differences go to the top for decisions. Again, effective relationships between the leaders are pivotal to success, and expectedly so, as the unit is part of the client's three-tier communication system, the others being project and then contract leaders. Each level of the tier works directly with the corresponding staff in the contractor organisations.

Under the project management system, though, finance is settled separately. Truschel recalls that the client advocated that MCG "trust in fair judgement" as the co-operative relationship was still developing. He did, and it has worked, he comments. The system also gave more certainty to both sides as all due payments, and other matters, are settled quarterly. No outstanding questions remain, they say. This uncommon system sees final determination and sign-off in top-line meetings.

Again, what is possible comes down to people, striving to deliver on what is said, promised, as Christensen says. It's about productivity. Output. Action.

The approach to risk, and therefore project management is being used across the entire project, not only on the tunnel contract. However, when the tunnel sector's international insurance code for risk management came out the client found that its system – developed beforehand – was almost totally compliant, it says. An appendix to address such matters was included in all contracts.

When it was seeking project insurance, therefore, the client put forward the entire project management approach that has a special focus on risk management. It echoes the experience of the Øresund Crossing where a key realisation was that those responsible for activities should also be responsible for risk management; specialists should only act in support roles. The value of experience and leadership comes to the fore, but the system developed under Larsson also demands greater responsibility. Delivering on that calls for good, effective and deliberate relationships, and co-operation, as Malmö has shown.

The experience is atypical; not every contractor, or client even, gets to operate in such a fashion. But coming from Øresund, it has been verified in Malmö. Christensen says the approach is best suited to major infrastructure projects being executed on a design and build basis. Where next? T&T

Copenhagen plans Cityringen

Cityringen is the next, entirely underground, phase of Copenhagen's metro. With tenders due to be called next year, contributing editor, Patrick Reynolds, recently caught up with the project team

While not boasting an extensive and long history in tunnelling, Denmark has been making its mark over the last two decades – not only in the TBM drives for the Storebælt link and then the immersed tube tunnel in the Øresund Crossing but also with the TBM drives for its recently built metro lines in Copenhagen. Now the city is looking ahead to the next phase of the metro – Cityringen – a 15km long loop to be built entirely underground, in twin tunnels and with 17 stations, by 2018.

A prequalification call for the civil works is to be made towards the end of this year and tender documents are to be issued around mid-2009. At this stage, it has yet to be determined if there will be two or three civil packages, but each will include tunnel and box station construction.

While the client continues with its site investigations, it anticipates that four or possibly five TBMs will be required for the project. From the geological data so far it is assumed that there will be both EPB and slurry shields on the project, and three potential locations have been identified for launch sites. The client is also considering taking relatively more risk for ground conditions compared to the first metro lines by providing its interpretation and assessment of the site investigation data.

Metro development

Copenhagen metro has two lines, M1 and M2. They were built in three phases and opened between 2002-7. Cityringen constitutes Phase 4 and will establish the M3 and M4 lines, the former running a loop, the latter a "pinched loop" on the east side of the ring. The end result will be driverless trains every 100 seconds in the east and 200 seconds elsewhere.

Studies for Cityringen were done over 2003-5, and funding was agreed in September 2005. Soon afterward a technical report was submitted for political consideration, which was quickly approved and by June 2007 the enabling legislation was passed, leaving a public enquiry for this year, as preparations mount for the construction phase.

Before procurement could get going though, there was an unconventional step - the metro owner changed. The owner Ørestad Development Corp, had a portfolio of land and rail development, and those combined responsibilities ended with its dissolution and the creation of a new metro client - Metroselskabet – on the same day, 26 October 2007. Key staff transferred, including Arne Steen Jacobsen as project director (he was project manager of design and also tender management consultant in the early phases of the metro).

Cityringen has a project programme that runs from June 2007, when the legislation was passed, and runs for 11 years in two blocks - three years for design and procurement, and eight years for construction, fit-out and commissioning. At the opening of the first phase of the metro, in 2002, early estimates of how long Cityringen would take to realise and when it would open were eight years - still with three years for design and procurement - and 2012, respectively.

The budget was set in 2005 when the technical report with project options was being drafted, and is DKr15bn (May 2005 prices – US$2.58bn at that time, almost US$3.2bn today assuming no change in local currencies but accounting for currency changes). Two-thirds of the total has been committed by the owners: Copenhagen Municipality (50%); Transport Ministry (41.7%); and, Frederiksberg Municipality (8.3%). The remaining third will be provided by debt (borrowed against future revenues).

In comparison, the first sections of the metro network were developed with underwriting by the government in the late 1990s. There was confidence in the project as the city would benefit economically from the Øresund Crossing to Sweden.

Looking farther ahead, Copenhagen Municipality is providing an extra DKr200M (US$42.3M) for studies of branch lines, and build stub tunnels.

Project management

Metroselskabet has an established project management team of 30 staff led by Jacobsen. The project manager for civil works is Jens Hieronymus Gravgaard, who was on the station design team in the early phases of the metro development and most recently was on the Citytunnel project in Malmö, Sweden (see p15).

The organisational structure has been set up for the three year long, first stage of the project. A decision has yet to be made on the construction management and supervision strategy, and its consequent organisational structure. With 150 people on project at present, including approx 120 consultant staff, everyone works in the co-located office that is also Metroselskabet's headquarters where the metro operations unit (approx 50 staff) is also based.

With the project one year into its 11 year programme, the consultants and their respective activities, are:

- Civils: a JV of Cowi, Arup & Systra
- Rail: a JV of Ramboll/Atkins, with Parsons as subconsultant
- Areas, Rights & Utilities (i.e. preparatory works): Cowi and subconsultant LE34
- Operation & Maintenance: done by internal client staff

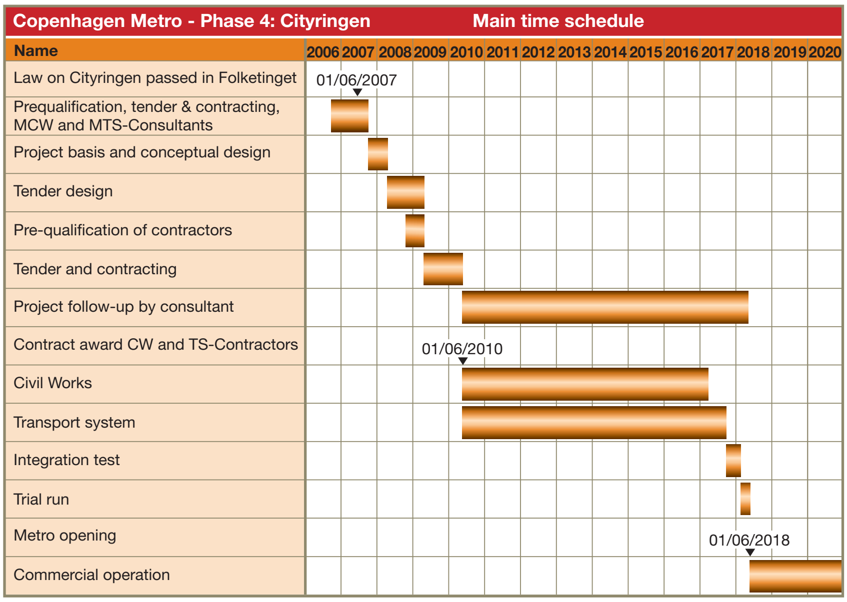
The client also requires the consultants to have multi-disciplinary capability to service all project needs and to be able to communicate effectively with one another. Additional contracted services include legal advisors and also the Independent Safety Assessor, TUV Rheinland with subconsultants Rovsing and DNV.

Comparatively, there are fewer distinct consultancy hires in contrast to the first phases of the metro. This is primarily because the public, and therefore the client, is settled on keeping with the concept design, and look and feel – the space, aesthetics and flow – of the initial metro lines, especially in the stations.

Procurement

Prequalification notices are to be issued by the end of this year, and the process

Below: Project programme for Cityringen in Copenhagen; **Below right:** Earlier tunnelling work on Copenhagen metro



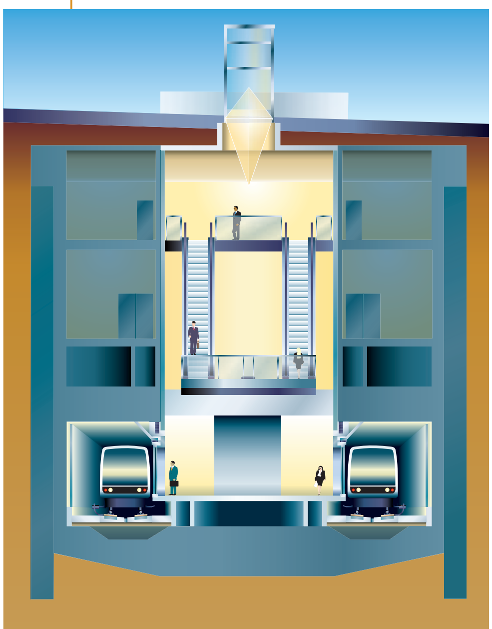
Above: Cityringen will have more sands to drive through compared to earlier phases of the metro. Slurry TBMs are being considered as well as proven EPB in the main limestone strata

completed in about the second quarter of 2009 – a little after the conclusion of the local authority review of plans and final input from extra site investigation.

Tender documents are to be released in about a year from now, and a negotiated procedure will follow submissions (for the first metro lines, three rounds of negotiation led to two final bidders and the winner was chosen on the final judgement of both price and quality). Contract awards on the separate rail and civil works packages are anticipated in about early June 2010.

A single contract package is planned to fit-out and operate the driverless metro transport system for approx 5-8 years, it is estimated. The contract will be for services only on M3 and M4, and is unrelated to M1 and M2, for which Ansaldo last year had its five year term extended, by a three year option, to 2010.

Below: Cityringen will repeat the design for passenger space (lighter area in diagram) and the competitive construction challenge will be outside of these areas (i.e. darker areas)



The civil works procurement will be undertaken differently from the first metro lines, not least because of the scale of the project. Depending on the final number of contract packages, and the boundaries, there will be up to three potential TBM launch sites for the twin bore tunnel drives:

- Cityringen's control & maintenance site, in the south
- A park at Norrebro, in the west
- A lake near future Trianglen station, in the north, where temporary reclamation would be needed

Metroselskabet's strategy is to have JV's bid for individual contracts only. It will not request bids for combinations of contracts.

"They have to win them individually," says Jacobsen, adding that they will have more than one winning option, more than one chance to win. "We know about the international market for civil works and we're looking at how the project will appeal to contractor JVs."

Given the increased risk sharing being considered by the client, the competitive differences between contractors are seen as being more to do with logistics, temporary works, tunnelling methods, grouting, dewatering/recharging, etc – i.e. the focus is on classic contracting output on heavy civils. The competitive margins would be calculated from the scale effects won by repeating the method of works, where possible, over multiple box stations and the approach to the tunnelling solution.

Geology and tunnels

The tunnelling conditions in the capital are relatively favourable with glacial moraine over limestone, which makes up half the alignment of Cityringen. The prime challenges are determining mass properties of the rock and the strictly controlled urban groundwater regime.

A site investigation programme involving 350 boreholes has been completed. Based on preliminary data, a further round of investigation has been decided in the northwest of the city centre, in the Norrebro area, where there is relatively more sand. Plans are being refined, and tests are underway of a coupled system of vertical (borehole) and horizontal (along streets) surveys to help determine the limestone profile. The additional probing should start in about September and will involve 50-100 boreholes as well as geophysical surveys.

In the Norrebro area, the thicker layers of sand (meltwater deposited) are either side of Clay Till (moraine) with the lower layer over the limestone at a depth of 30m-35m. From the ground surface, the sequence is: Fill/postglacial deposits: (0-10m); Upper meltwater sand: (0-3m); Upper till/Meltwater clay (0-10m); Middle meltwater sand (0-18m); Lower (Clay) till (0-8m); Lower meltwater sand/gravel (0-18 m); Copenhagen limestone (20-40m); and, Bryozoan limestone.

On one occasion, in Phase 2 of the metro, on an EPB drive through sand between Norreport and Forum stations, and with compressed air being used, there was a blow out of the bed of lake Peblingesøen.

"The difficult parts for the EPB machine lie in the coarse sand and gravel deposits," adds Gravgaard, noting that there were no other significant incidents affecting settlement control.

Therefore, with a high groundwater level, the relatively greater presence of sand in the Norrebro area raises the possibility of using slurry TBMs for settlement control. The capability of slurry TBMs for use in limestone is also being investigated.

Unlike on the early metro phases, Metroselskabet, in considering taking on more risk, would not just give over raw data to tenderers but also its interpretation of the numbers, both for design purposes and to help deal with discussions with environmental authorities. The interpreted, or "evaluated", data for the civil works would see the client "probably giving some global design values", says Gravgaard, such as UCS, angle of internal friction, and how the strength of limestone is defined.

Copenhagen limestone has three subdivisions – upper, middle and lower – based upon combined markers from geophysical borehole logging, such as natural gamma, induction, resistivity and porosity. The subdivisions are characterised by five degrees of hardness (H1-H5), or induration. At the softer end, rock of H1 classification can be shaped with the fingers, H2 easily worked with a knife or scratched with a fingernail, and at the hardest, H5, there is flint. The subdivisions have different percentage distributions of H1-H5, and the upper and lower zones have more H5.

Metroselskabet will also tell contractors that the limestone is more competent than basic borehole data would indicate, thanks to facelog data during previous tunnelling works. Most fractures in core samples are due to drilling, says Gravgaard.

The existing metro tunnels are 4.9m i.d., spaced typically 20m between centrelines and a similar arrangement is anticipated for Cityringen. The M1 and M2 tunnels have six-segment, 275mm thick rings but the client is unlikely to specify such detail for the lining, nor the excavation diameter but is looking to steel fibres over rebar to improve durability and minimise damage during handling.

Contractors will be able to optimise the vertical alignment of the tunnels to minimise mixed face tunnelling as they benefit from the extra site investigation data, which is also aimed at better defining upper profiles of the limestone. Suggestions for excavation between the stations will be welcomed, says the client, noting it's a constructability issue but that ground treatment is assumed to minimise settlement, especially for any proposals for shallower tunnelling.

Stations - special challenges

Metroselskabet is undertaking new types of geophysical borehole logging (optical and acoustic televiewer) to survey insitu rock from boreholes. Previously, the methods were used on a local district heating tunnel, completed earlier this year. It has also been used at the proposed locations of cavern excavations and for lower parts of two of the most complicated construction challenges for the stations – at Frederiks Kirke and Kongens Nytorv.

At each station, the open box construction is narrower than standard on Cityringen. At the base of the diaphragm walls excavations will be broken-out using NATM to form caverns for the platforms and pull through the TBMs for relaunch.

One of the country's most beautiful old churches, built on timber piles in saturated strata, is Frederiks Kirke. The construction challenge arises from the proximity of the new station. The platform will be just over 24m below the surface, deeper than the approximately 18m-19m at most stations.

The challenge is added to by the need to keep the timbers below groundwater level, and therefore a major operation of dewatering and recharge will be required for the deeper than typical station excavation.

Kongens Nytorv is the capital city's finest square and is bounded by the Royal Theatre, the main shopping street, and outside dining/café areas. In addition to the public prominence in one of the most valuable real estate arenas, the construction challenge includes connecting the new station to the existing one with a platform approximately 18m below ground surface. The plan is to go deeper, drive the new running tunnels below, but close to, the live tubes, resulting in a new platform depth of approximately 28.5m.

Going deeper at Kongens Nytorv also adds to the need for a powerful groundwater control regime. Groundwater protection is a very serious business in Copenhagen, as elsewhere in Scandinavia. In the central part of the city the level cannot be lowered due to settlement risk. It is also a zone of potential drinking water interest. In fact, even getting a permit for a drawdown pumping test proved a difficult process, comments Gravgaard. Further, there are strict and onerous limitations on insitu concrete, shotcrete and grout additives.

The scope and details of the project, and competitive build options, will become clearer over the next couple of years. T&T

Beauty is in the eye
of the beholder

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

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

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

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

Visit us at

2008 MINEXPO INTERNATIONAL

September 22–24 • Las Vegas, Nevada • USA

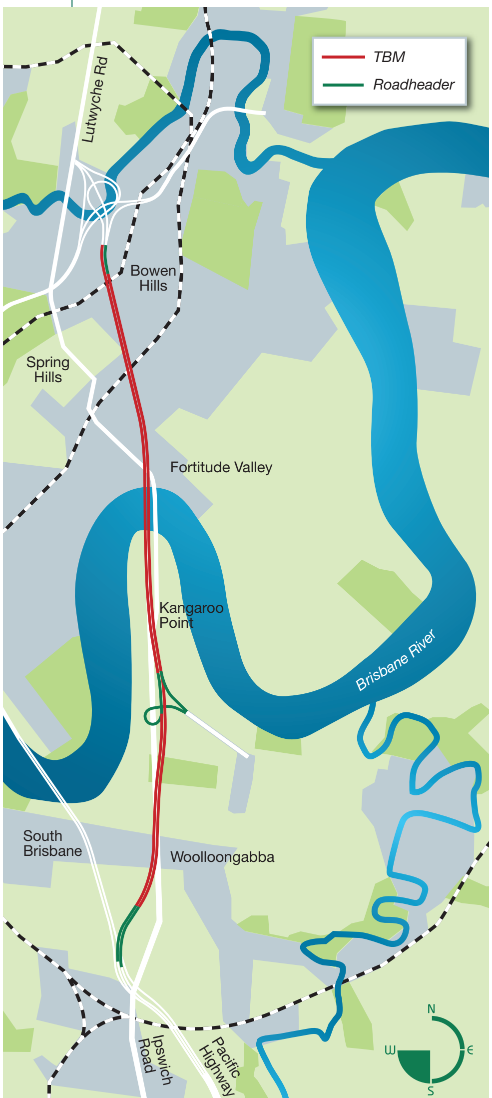
www.minexpo.com

SANDVIK

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

Brisbane's central city tunnel

Brisbane is currently building the longest road tunnel in Australia, for traffic congestion relief in the city centre. Report and photographs by technical journalist Adrian Greeman



Above: **Plan map of the alignment of Brisbane's north south road tunnel**

Australia's biggest hard rock TBMs, identical 12.4m diameter Herrenknecht machines, are now well at work underneath Brisbane capital of Queensland state, creating a new underground motorway link for the city. It will be the country's longest road tunnel and is going reasonably well.

The first drive started in January and the second in March and both are steadily pushing forwards, to pass eventually under the Brisbane river and down the long Kangaroo Point peninsula, an area formed by an extended loop of the river and a sharp bend at the top. It finishes in South Brisbane.

The twin drives will be 4.8km each, though the machines will cut only about 4km of the total length, since a central interchange section halfway down the Point, has a variable cross section and must be made by roadheaders. The whole road length will be longer still, because work includes some fairly complex three level interchanges with a variety of bridges and ramps at each end; these will connect the new tunnel into the city's existing highway network.

At the south of the project this means a link into the Pacific Highway, the out-of-city continuation of the main road through the city to the Riverside Expressway down to the famous Gold Coast.

On the north side the connections will be made into the often busy Inner City Bypass which feeds commuter traffic into the nearby central business district from the north and west suburbs.

A tunnel allows the busy city centre to be avoided and will be an important relief route for major congestion caused by peak hour crosstown traffic. At present there are few alternatives to the Riverside Expressway bridge or the well-loved but limited capacity Story bridge for highway 15 at the end of Kangaroo Point, just above where the tunnel will cross.

Traffic is growing day by day constantly as the city grows in importance. As everyone in the southeast of Queensland constantly tells you, the population is rising in Australia, but most of all in this area where an additional 1500 people move in on average every week. A tourist friendly climate, finance and the minerals boom stimulated by the growth of China are the magnets; Queensland has big reserves of coal and other raw materials - and magnificent surfing.

Taken together these factors should be enough to make a road tunnel both feasible and self-financing the Brisbane City Council believes, and it has opted to make the project a toll road, built as a public-private-partnership. The concession, a forty-five year finance, build, own operate contract is with the RiverCity Motorway Group (RMC).

RCM in turn has let the US$1.9bn project design and construction to a joint venture of Australian firms Leighton Contractors and Baulderstone Hornibrook, and parent company German contractor and tunnel specialist Bilfinger Berger. The resulting LBB JV has Maunsell/Parsons Brinckerhoff joint venture as its design firm and Golder Associates for geotechnical work.

Time restraints

A key challenge of the job, is to get it completed quickly, to alleviate the city's traffic and naturally enough begin the collection of tolls to establish the revenue stream.

"We were given a very short delivery time" says project director Adam Hudson for the JV, "beginning work in August 2006 and with a completion date for October 2010." At present the contractor hopes to pull even that date forwards, finishing at the end of 2009.

The tight programme is the main reason for choosing two very large TBMs rather than one single TBM making a return trip which would extend the programme, not only of the main excavation but follow on work and ancillary work.

The programme boost has been helped further by a fast delivery for both TBMs by Germany manufacturer Herrenknecht, supplying the first in 13 months. The first machine was commissioned in December 2007, with the second in March 2008.

"We got a good start too because of several months of pre-contract discussions when we were in a preferred bid position" says Hudson. It meant enough design work had been done to place an order for the machines "on day one" he says.

The machines themselves should keep the pace going. They are reasonably powerful with 5700MW of onboard power each and should handle the fairly hard ground comfortably. Two types of rock predominate, Brisbane Tuff, which is appropriately quite tough, being a welded volcanic ash of between 80MPa and

Above: **One of the Herrenknecht TBMs**
Left: **Segment erection underway using the TBMs automated erector machine**

50MPa, and Neranleigh-Fernvale metamorphic and of similar strength. Both types are potentially fairly abrasive.

"The formation involved clays and other material buried under hot ash and transformed, possibly unpredictably" he says.

The TBMs are also telescopic, double shield machines with the capacity to jack the cutting head forwards from the gripper section while the segment handler is still placing the ring behind. With grippers withdrawn that section can then push off the completed ring behind while the cutting head continues forwards too.

"In double mode therefore you can build segment rings at the same time as you are cutting" says Martin Wieser, TBM project manager at the site. That will allow around 10 rings to be placed daily once the crews have fully worked through a learning curve. With segments of 2m across that is 20m, around 100m in the five day week the machine will operate.

The tunnel's primary lining is the precast rings, comprising eight full segments and a half size key unit. Segments are 400mm thick and occupy 4.5m of the ring circumference each; they weigh in at 9t placed with a Herrenknecht automated erector machine.

In double operation the rings are partially backfilled with pea gravel and only the top of the annulus will be grouted with a normal cement grout says Wieser; in single mode operation the placing is reduced to around 12m a day and there is time to inject grout fully around the ring.

The double head is not the whole story with the machines however. They also have the capacity to seal off the section behind the cutter head resisting up to six bar pressure, though in this condition they can only operate in single mode.

"The ground is rather varied to get through with two sections with a lot of broken rock and the potential for water passage" says Hudson. A major geotechnical investigation "with a 'forest' of boreholes" has also been carried out in the area he adds.

"There are a number of fault zones along the route, but we are not too concerned. The next issue really is at the river where there is the possibility of a bigger fault and the capacity to use the machine under pressure is to guard against that." The machine will be 60m deep at this point, the lowest of the tunnel drive.

It is insurance really, and Wieser says he is hoping the machine will not need its pressure mode at all. But forward probing is carried out regularly as the machine progress, up to 65m ahead. If water is encountered, the ground will be grouted from the sealed head.

Up and running

Getting the machines running well and crews familiar with the sequences is ongoing. Tunnellers are drawn from worldwide, reflecting the busy market in Queensland and are being trained with aid from Herrenknecht personnel.

Production rates so far had not reached the eventual levels said Hudson in May when *T&TI* was on site, but he was confident they would get there.

But many other factors affect the speed of work too. Outside the machines, careful planning for logistics and sequencing of works around the main drives is just as important, not least because of the cramped urban conditions for the project at all three of its main sites. There are significant community issues, demanding major noise controls and care with truck movements.

The biggest site is at Bowen Hills, just opposite the city's historic exhibition grounds, the first area to be tunnelled under. This is the launch site, spoil handling facility and also a major construction area itself, because of the three level interchange which is needed.

A launch pit was excavated here in three months inside a steel "shed" which gave weather and noise protection for the portal creation and erection of steel launch rings for the machines.

"A 125m long TBM cradle was constructed in both mainline tunnels leading to a TBM launch chamber and a steel launch ring erected at the outer face of the launch chamber for the front sections of the TBMs to 'push' off.

Complex sequencing of traffic on the roads around has been crucial, and Maunsell had its own team working on diversion layouts.

Around the pit the contractor has been building the bridges and ramps for the connectors from the highway. These have to cross a road, a railway and a local creek which has to be protected.

The ramp work has been cleverly combined with the spoil removal system, by opening the first sections early as dedicated entries for the big "truck and dog" and "truck and super-dog" lorry-trailer combinations which haul it away directly onto the arterial road network. They can thereby avoid the local roads altogether, which would otherwise have to cope with up to 350 trucks daily.

Trucks are loaded within one of two purpose built storage silos of 7000m^3

capacity each, fed by the conveyor system that runs from the back of the machines, carrying away over 10,000 tons of rock chips per day. Fortunately for the project the high construction activity in south Queensland means high demand for the total 3M tons of spoil, especially along the marshy river estuary where the old airport is being converted for industrial use, and contractors needs the fill.

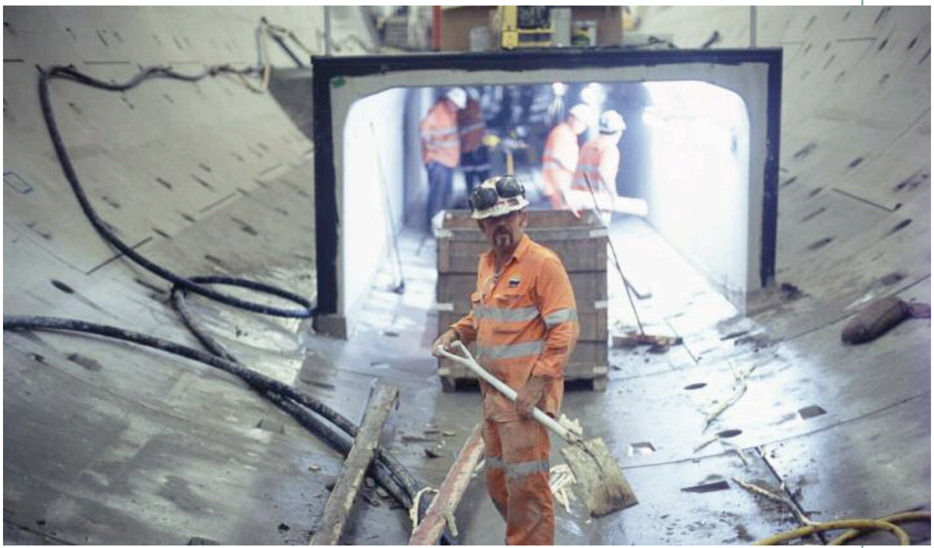
Everything is soundproofed with high-attenuation absorbent panelling; the loading shed, the conveyor enclosure and even the box which holds the folded extension sections for the conveyor. "It is expensive but a crucial investment when there is a need to work 24 hours round the clock in the city" says Hudson.

The Bowen Hills site is also the reception area for the materials used in the tunnel; most of all the 37,000 ring segments, which are delivered more or less on a just-in-time basis because of shortage of space. They arrive on drop-deck trailers from a special precast facility set up, as it happens, near the airport at Eagle Farm. It has its own batching plant and steam curing facilities and turns out 700 units a week.

On site rubber tyred two-way towing units from Terberg carry the segments to the back of the machine where they are lifted and transported forwards to the head.

The TBMs are long, some 212m with a bridge section in the centre. The trailing sections of the machine run on the already laid tunnel floor which is formed immediately behind the machine head in the "bridge"; precast concrete culvert sections go onto the invert for cabling and drainage and the gap to the tunnel wall is backfilled and compacted.

Other expensive equipment at site includes a full water treatment plant. Queensland has been suffering a severe drought for seven years and reservoirs were down to 15% at one point in the summer, though some rain did come this year.



Above: **Work underway in the tunnel invert**

Water restrictions remain at Level Six however, which virtually eliminates construction use. As a result the contractor has installed water treatment plants at its three sites and the precast factory.

"The largest at Bowen Hills is an ultra filtration plant that can produce up to 45lt/s with a storage capacity of 1M litres. A reverse osmosis plant is also installed that can produce up to 7.5lt/s with a storage capacity of 1.5M litres" says Hudson.

Kangaroo Point

Meanwhile work has had to press ahead at the other two sites, especially at Kangaroo Point halfway along the project. A tunnel level interchange is needed here with ramp side tunnels and slip lanes, and it must be ready by the TBM arrivals, as they will be pulled through to re-start on the far side.

A variety of roadheaders have been working on this extra large cross section portion – there are eight 330Kw machines altogether including four Wirth, two Voest Alpine, and two Mitsui.

The site has been going alright he says although it is very tight, "no more than a pocket handkerchief" says Hudson.

A couple of the roadheaders are now being used back at the main tunnel where they form the cross passages between the two main drives. These are very frequent, every 120m and have set the five day cycle for the TBM work.

"It needs two days to saw cut the lining and excavate the passage, which prevents the supply of the TBM" explains Wieser. The down time is useful for maintenance.

The frequency of the passages reflect high safety standards in Australia says Hudson; the request here was for a maximum 120m between access points for passenger escape into the opposite tunnel bore in the event of fire or accident.

The escape routes are part of a comprehensive safety system for the two 3.5m lane tunnels and safety shoulders of 1m and 0.5m.

That will include electronic detectors from smoke and heat detectors to video incident detection and CCTV. Variable message signs, and speakers will provide information and there is a radio override system, which break into civilian radio when needed.

"We will also have a full fire deluge system" says Hudson. This dumps a mass of water at a fire site to swamp it and is now an established precaution in Australia, though not much used outside. Ventilation is longitudinal with 119 jet fans of 900mm diameter venting 600m^3/s of air at each outlet. "Exhaust is discharged in a vent stack at the exit portal."

Final fit-out will include a fully electronic tolling system with tolls to be around A$3.5 (US$3.3) index linked. T&T

Below: **Lining works at one of the tunnel portals**

An introduction to International Arbitration

International arbitration proceedings is an area of contract law that once involved in, will seldom be forgotten. *T&TI's* contracts and disputes correspondent, Paul Cullinan of Plus 3 Consultants, overviews this potentially bruising process for the ill prepared

Many construction and engineering professionals will go through a whole career without being involved in a dispute which eventuates in full-blown international arbitration proceedings. Anyone who has will know what a bruising process it can be and will not be keen to be involved in a second. However, the drafting of an agreement for dispute resolution is sometimes known as a 'midnight clause', that is, it is something which is left right to the end of contract negotiations, perhaps even at midnight on the final day. So, whilst this article describes some of the processes and considerations for those unlucky enough to actually become involved in an arbitration it also gives an insight into matters for those involved at the front end, drafting contracts.

An arbitration agreement

Without an arbitration agreement parties to any contract will have default recourse to the courts in the country which governs the contract. By entering into an arbitration agreement the parties are agreeing not to take the matter to court but to have the matter in dispute resolved in private by a neutral third party. Aside from the noted element of privacy, choosing arbitration over litigation has the advantages that there is generally more party control over the proceedings; one has the option of choosing a subject matter specialist arbitrator and, of particular importance in the international arena, any arbitration award will be enforceable in other jurisdictions.

This latter point was dealt with in a previous article, but shortly, there is no point in having a judgment or arbitration award in one's favour if it cannot be enforced. Taking a judgment from one jurisdiction into another is problematic as it is unlikely that the judgment will be enforced in the second country. However, the New York Convention On The Recognition and Enforcement Of Foreign Arbitral Awards 1958 says that signatory countries will enforce arbitral awards made in other signatory countries. The 1958 Convention has been widely adopted around the world so there is a better than even chance of enforceability of an arbitral award in another jurisdiction.

Likewise, most jurisdictions in the world will respect a party agreement to have disputes settled by arbitration rather than litigation, meaning if one of the parties to the arbitration agreement does start court proceedings then the other can approach the court to have those litigation proceedings 'stayed' by presentation of no more than the fact that there is an arbitration agreement.

What arbitration is not generally good at is multi-party disputes, where court proceedings will normally readily allow the

'joining' of other parties as joint defendants, with the court's inherent jurisdiction to back such moves. Arbitration on the other hand must be played by the rules set out in the arbitration agreement. If there is a series of parties on a project, for example consulting engineer, main contractor, sub-contractor and suppliers, then in order to have the advantage of all disputes in the chain, which are probably reliant on the same basic facts, being joined in the same proceedings then each of the contracts in that chain will have to contain back-to-back arbitration agreements. Achieving such a co-ordinated approach is not easy and takes careful forethought in procurement planning.

Terminology

The terminology of arbitration agreement as opposed to arbitration clause is useful when one considers that an arbitration agreement can be inserted into a contract at the outset, but equally a separate agreement can be reached at the time when a dispute arises, even if the original contract did not call for arbitration. Any separate agreement would be recognised and enforced in the same way as any included in the original contract.

Reference to an arbitration agreement is also conceptually useful when considering another feature of an arbitration agreement, which is the doctrine of 'seperability'. This doctrine, again recognised in many jurisdictions in the world, says that in the event that a contract is terminated, either by agreement or by default of one of the parties, then the arbitration clause will survive such termination, such that disputes arising before the termination, and in many case the validity of the termination itself, can still be referred to arbitration under the arbitration agreement.

Layers of control

The conduct of an arbitration can be characterised as having four layers of control, some will be mandatory, some optional, the degree of control will depend on the arbitration agreement. The four layers are:

1) The arbitration agreement itself.
2) Any standard rules incorporated into the arbitration agreement by reference.
3) The control exercised by an arbitration body in what is know as an 'institutional' arbitration.
4) The arbitration law of the jurisdiction which governs the arbitration agreement.

Considering each of these in turn:

1) *The Arbitration Agreement*

Aside from the clear mention that the parties agree to arbitrate there is no special form that an arbitration agreement should take. And so there is scope for the parties to finesse the drafting of the clause in any way they wish in terms of the choice and composition of the arbitral tribunal and any special limitations the parties wish to place on the conduct of the arbitration, for instance but perhaps unusually, the parties might agree that each side bears its own costs in conducting the arbitration regardless of the outcome on matters of principle.

2) *Standard Rules*

One matter in particular that the parties can choose in their arbitration agreement is to incorporate by reference standard rules for the conduct of the arbitration. There are many different forms of standard rules, normally issued by trade or industry bodies. Often one may get standard rules as part of the 'package deal' of using a standard form contract, for example the ICE standard forms will incorporate the ICE's own standard set of arbitration rules.

Standard arbitration rules will typically be quite detailed and deal with those matters that are most likely to arise during the course of the arbitration, such as selection and appointment of an arbitrator, exchanges of pleadings, disclosure of documents and the procedures for dealing with witness evidence.

3) *Control By Arbitration Body*

Here there is normally drawn a distinction between what are known as 'ad hoc' and 'institutional' arbitrations. 'Institutional' arbitrations are where the arbitration agreement calls for the arbitration to be conducted in accordance with the rules of an arbitral institute which exercises a high degree of control of the whole arbitral process. The best known, and probably most controlling, of these in international construction and engineering is the International Chamber of Commerce, International of Court Arbitration, Rules of Arbitration (ICC). Others such institutions include the London Court of International Arbitration (LCIA) and Stockholm Chamber of Commerce. The use of the word 'court' in these titles is somewhat misleading in that they are not in any sense national courts.

An institutional arbitration will mean that appointment of the arbitrator; the terms of reference and even scrutiny of the award drafted by the arbitrator before issue to the parties will be conducted through the conduit of the institution. Whilst this may give any eventual award a high degree of robustness in terms of it being more readily presented to a national court for enforcement, it comes at the expense of an additional layer of cost for the institution's fairly close monitoring and administration of the arbitral proceedings. The levying of these costs varies from institution to institution with for example the ICC charging a fee based on the amount in dispute and LCIA charging fees on an hourly rate for the involvement of their administrators and officials.

For clarity, a distinction should be drawn between a full 'institutional' arbitration and the involvement of either certain trade or industry institutions or one of the many arbitration institutions around the world that do not undertake the 'full service' monitoring of proceedings. These other trade bodies or arbitral institutes may have standard arbitration rules and in some cases even appoint an arbitrator when requested, but take no further part in the proceedings. These are not considered as 'institutional' arbitrations.

Ad hoc arbitrations is a catch-all term for everything which is not 'institutional' and itself can range from arbitration with standard arbitration rules to one where the rules for the conduct of the arbitration are a 'blank page' and the parties make up their own procedural rules, either at the outset or as matters proceed.

4) *Arbitration Law of the Jurisdiction*

Firstly it should be pointed out that the law which governs the underlying contract does not necessarily have to be the law which governs the arbitration agreement, remembering that the arbitration is in effect a separate, 'separable' contract. The reason for this distinction is that some jurisdictions have a reputation for being more 'arbitration friendly' than others in terms of the hands-on or hands-off approach of the local judiciary. Indeed many jurisdictions have gone to great efforts to attract the 'business' of international arbitration, this is not just creating a market for already well-healed lawyers but is more to do with creating what is perceived as a commerce-friendly environment.

So it is that drafters of an arbitration agreement may go 'forum shopping', that is to state that the arbitration agreement is governed by the laws of a country which may not necessarily be the same as the law governing the underlying contract. The jurisdiction of the law governing the arbitration agreement is known as the 'seat' of the arbitration, giving a sense of

"ANYONE WHO HAS, WILL KNOW WHAT A BRUISING PROCESS IT CAN BE AND WILL NOT BE KEEN TO BE INVOLVED IN A SECOND"

> **“THERE IS OBVIOUS ADVANTAGE IN BEING IMMEDIATELY FAMILIAR WITH THE PRINCIPLES, IF NOT THE DETAIL, OF ANOTHER JURISDICTION’S NATIONAL LAW ON A MATTER OF CONSIDERABLE IMPORTANCE TO A CONTRACTING PARTY, WHEN WEIGHING THE RISKS OF DOING OVERSEAS BUSINESS”**

that is where the arbitration is to be ‘held’. However that need not necessarily mean that the arbitration hearing will be ‘held’ geographically on that place. So one could have an arbitration where the ‘seat’ is France but for some reason, perhaps of convenience of the parties or their representatives, the actual hearing is held in New York. There are even instances of ‘roving arbitrations’ where some stages are held in one geographic location and some stages in another, however the ‘seat’ will always remain constant.

Each country will have its own arbitration law, for example the English Arbitration Act 1996, each national law will set out the degree to which a particular country will allow arbitration to, in effect, replace the inherent jurisdiction of the national courts. There is wide variation, hence certain jurisdictions having reputations for being more ‘arbitration friendly’ than others.

International attempts have been made to smooth out these differences between jurisdictions, principally by UNCITRAL, the United Nations Commission on International Trade Law. UNCITRAL drafted what it called a Model Arbitration Law, the intention of which was that countries would adopt, preferably without amendment, into their own national law. There has been considerable success in this endeavour with around 60 jurisdictions, from Armenia to Zimbabwe, having enacted laws which either cut and paste directly or follow closely the Model Law into their own national law.

There is obvious advantage in being immediately familiar with the principles, if not the detail, of another jurisdiction’s national law on a matter of considerable importance to a contracting party, when weighing the risks of doing overseas business.

Again some clarification is needed between the UNCITRAL Model Law and the ‘UNCITRAL Arbitration Rules’, the latter are more akin to standard arbitration rules as described above, which have been drafted to be incorporated by reference into an arbitration agreement.

Conclusions

From the above it can be seen that there are many matters that should be considered before one has even taken the first step in an arbitration in the international arena. Having at least a working understanding of these principles should assist either when a move to arbitration is becoming inevitable, or else when it is close to midnight on the last day of contract negotiation and the lawyers are bamboozling everyone trying to close the deal. T&T

Core drilling for HK's HATS Stage 2A

Shteryo Lyomov, associate professor with the Dept of Drilling, Oil & Gas Production, at the University of Mining & Geology, Sofia, discusses directional coring techniques used as part of the HATS Stage 2A ground investigation works, in Hong Kong

Above: **Drill site and drill rig set up**

The Government of the Hong Kong Special Administrative Region through the Drainage Services Department (DSD) awarded a US$6.5M ground investigation contract for HATS Stage 2A on 14 November 2006. This is the first of two major ground investigation contracts planned for the scheme, which will intercept sewage from the north and southwest of Hong Kong Island and convey it to Stonecutters Island for treatment.

Under the contract some 40 vertical and directional boreholes will be drilled to investigate rocks at the tunnel location. Norwegian firm Devico, specialists in directional core drilling technology and borehole surveying, will design the inclined and directional boreholes at the project's proposed shaft locations. These will be performed using the DeviDrill system, which consists of wireline steerable core barrel, measure while drilling system, and PC software package for borehole design, planning, and survey calculation and reporting. Continuous rock sampling along the tunnel alignment at strategic locations is also being performed using directional coring techniques. Over 5000m of directional core drilling has been undertaken so far.

Below: **Devico project manager Grigor Topev explains the DeviDrill system principals to Drainage Services Department engineers**

Borehole design

The aim is to obtain as much information as possible from the directional boreholes for use during further design and tunnel construction. The borehole paths follow the tunnel alignment and are restricted to the safety envelope. Core samples OD 31.5mm are collected, with the paths initially determined based on the specific tunnelling requirements at the location under consideration.

The actual borehole profiles are designed using Devico's software design package DeviSoft, and various scenarios are discussed with the project Engineer, Metcalf & Eddy/Maunsell JV. The optimal borehole path is then selected and the information passed to the responsible drilling contractor for execution.

Experience gained on other ground investigation projects in Hong Kong, such as the Eagle's Nest twin tunnels, Tsuen Wan Drainage Tunnel Project and Landslide Preventive Works at Po Shan Road, where granitic rocks dominate, has shown that the optimal length of the directional borehole is in the range up to 1200m -1300m. When drilling longer horizontal boreholes special care is required for orientation of the steerable core barrel and drill string tripping operation.

Drilling operations

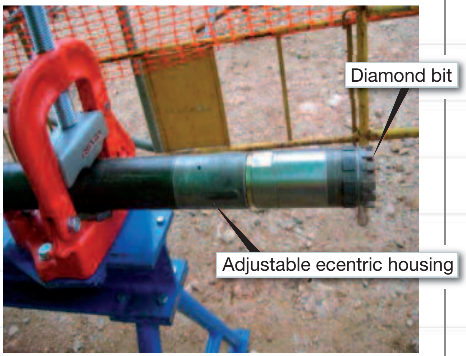
Following drill site and drill rig setup, commencement of the drilling operations begins. The long horizontal drill paths mean much higher frictions on the drill string, when compared to vertical boreholes of the same length. It is therefore important that the drill rigs used have the necessary power in terms of torque, WOB (weight on the bit), and pull and push forces to run the drill string in and out of the borehole.

The drilling process includes several steps. First, conventional drilling is employed to drill the straight sections of the planned borehole. Here a wireline NQ core barrel system is used. When the borehole reaches the section where steering is required, the DeviDrill system is adopted.

The drill string is pulled out of the hole and, following hydraulic testing and adjustment of the dogleg settings (the eccentric sub that is responsible for the deviation of the borehole in the direction set), the DeviDrill is employed. Orientation is performed and drilling is initiated. Control borehole surveys are carried out in order to determine whether the borehole is following the designed path. If needed corrections are performed by changing the dogleg setting of the DeviDrill.

For the initial section of the boreholes, where unconsolidated, weathered granites are present within the soil matrix, a casing string is used to maintain borehole integrity. The casing string is not cemented and after completing the borehole it is pulled out.

Drilling fluid additives such as polymers and lubricants are used to reduce the friction between borehole walls and drill string. During the directional core drilling strict and precise control of the drilling



Above, from left to right: **DeviDrill hydraulic test before running in hole; DeviDrill orientation; Dogleg eccentric housing**

parameters – WOB, rotation speed, mudflow rate, etc. is required. These parameters directly affect daily production rates.

Maintaining the mud pump pressure to guarantee a stable tool face is one of the main factors in controlling the borehole path after orientation.

In addition to the geotechnical conditions at the location, deviation response during borehole steering in the directional borehole sections has shown a dependency on the dogleg setting of the DeviDrill system. Experience from the HATS project shows that a build-up rate in the range of 10-12°/30m is the limit where drilling constrains do not influence the overall drilling process.

During drilling, borehole instabilities have been faced in some sections. In these cases cement plugs and grouting are used to stabilise the rock. Then the drilling operations are resumed.

Further applications

Directional core drilling applications provide indisputable advantages compared with conventional wireline drilling. The ability to closely follow borehole trajectory tolerances using this technology helps obtain a better quality of geological information, as well as reducing drilling and project time. Savings in the range of 50% can be both feasible and realistic. T&T

Sound Transit Seeks Industry Review of University Link Tunnel Contract U220

Sound Transit invites potential bidders and other interested parties to review a draft Invitation for Bid package, including 90% plans and specifications, for the University Link Contract LR 1-09: U220 – Bored Tunnels from the University of Washington Station (UWS) to the Capitol Hill Station (CHS) and University of Washington Station Excavation and Support in Seattle, Washington. This contract includes the excavation and earth support for the University of Washington Station box and crossover structure and the 2.1 miles of twin-bored tunnels that run from it to Capitol Hill Station. The tunnel work includes all civil works (e.g. track-slab, walkway, raceways), and cross-passages.

Sound Transit plans to issue this Request for Industry Review on July 16, 2008 and requests industry comments on the draft contract documents by August 15, 2008. Potential bidders and other interested parties are requested to send an email request to receive a copy of the Industry Review documents to Sue Craven, Sound Transit's Sr. Contracts Administrator at sue.craven@soundtransit.org.

LA's soft ground cross passages

Christophe Bragard and Brett Zernich, of Traylor Brothers, and Johannes Jäger, of Beton-und Monierbau, describe the SEM construction of cross passages through soft ground in Los Angeles

The US$900M Metro Gold Line Eastside Extension (MGLEE) will be a 9.6km twin track light rail route built for East Los Angeles. Part of the overall scope of this project included a 2.4km sub-terrain section with two underground stations, twin 5.7m i.d. bored tunnels, six cross passages, and two sump structures (figure 1).

The subcontractor for the US$125M design-bid-build tunnel contract is the Traylor Brothers Inc/Frontier Kemper JV (TFK), with Washington Group/Obayashi Corporation/Shimmick Construction Co JV as contractor. The Owner is the Los Angeles County Metropolitan Transportation Authority (MTA) with the Parsons Brinckerhoff/JGM Engineers/Barrio Planners JV acting as designer, and Kellogg, Brown and Root and Carter & Burgess, Inc charged with construction management.

This was a high profile undertaking for the MTA as problems on previous subway ventures had delayed this and other regional underground projects. This put even more pressure on the Contractor's performance, not only for the TBM tunnels, but for the construction of the six 5.5m diameter, 7.3m long cross passages.

Geology

All cross passages were within an alluvial zone, classified as Old Alluvium (Qoa).

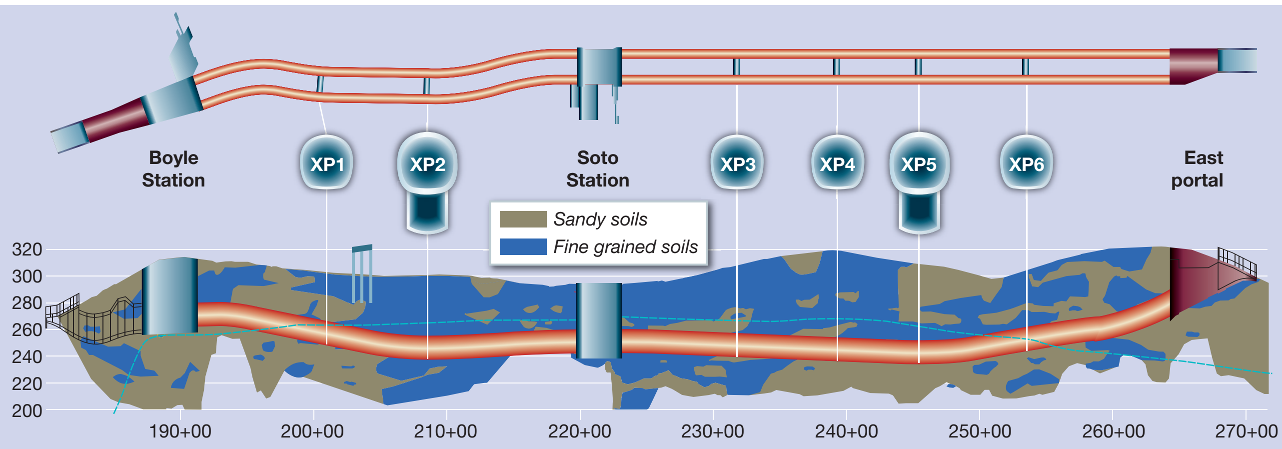
The soft ground varied significantly across the alignment and consisted of coarse sands, silts, fine clays and any combination thereof. This posed a host of challenges from a ground treatment perspective. Also, groundwater was present at each cross passage location, with water head varying from 1.6m to 14m above invert. Mining below the water table within alluvial soils was a cause for concern to the designers and builders, as dewatering from surface was prohibited under the contract for environmental reasons.

The alignment was classified by Cal OSHA as "Gassy" prior to excavation. Based on the experience gained boring the alignment, the engineering team did not expect high concentrations of gas, but was aware that it still might encounter methane, benzene, or hydrogen sulfide anywhere.

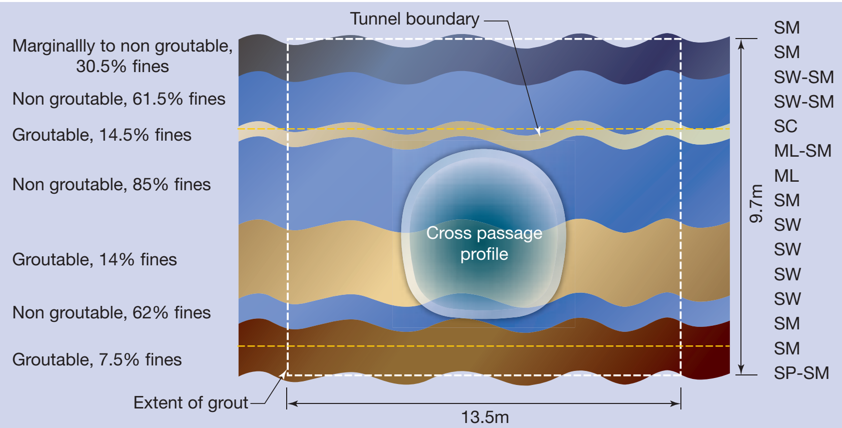
Method selection

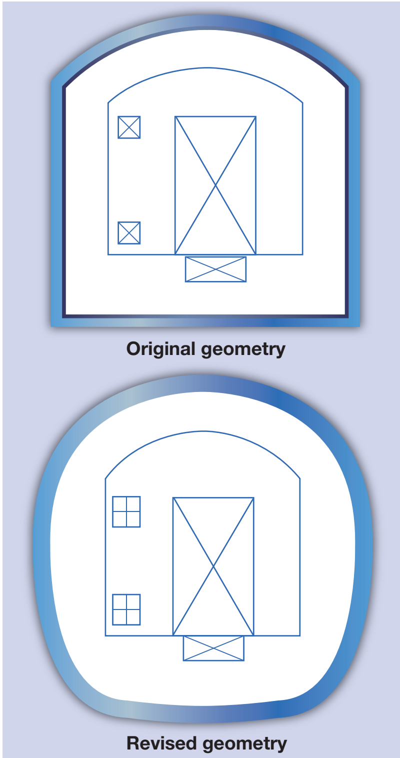
The contract required the use of chemical grout within the cross passage excavation by a prequalified grouting subcontractor that was to design the ground improvement scheme. Early in the project, the selected subcontractor (Hayward Baker) performed a series of pre-construction borings to further investigate the ground conditions at the exact cross passage locations. From analysis of these and the contract drawings, TFK expressed apprehension about the grouting guidelines shown in the contract. Risk of heave, groutability, and grouting zone dimensions were among their concerns.

It was decided that; the grouting zones should be independently designed, according to depth and water conditions; the groutability of each soil layer had to be



Below: Fig 1 – Project alignment map and cross section of the geological profile





Above: **Fig 2 – Groutability of cross passage 1**
Right: **Fig 3 – Round cross section geometry and original cross section geometry**

considered more carefully; and that the geological strata should be considered in the design of the temporary excavation support, reflecting groutable and ungroutable zones.

In the contract drawings, the final concrete cross section of the cross passages was designed as a horseshoe. This prompted TFK to bid the work with the intent of using ribs and lagging as temporary support. After further ground analysis, this did not seem correct for the actual conditions due to the presence of many ungroutable and/or partially groutable layers which could cause water infiltration, raveling ground, settlements, gas infiltration and ground instability.

The layers that involved the most risk were the partially groutable layers, mostly silty layers. The silty soil would only allow part of the chemical grout to infiltrate the matrix, while other portions would be too dense for grout to penetrate, allowing water to permeate through the ground reducing face stability (figure 2).

TFK addressed the client with the issues raised. Jointly, they reassessed the general construction method in a way that would ensure better safety. TFK decided to involve the Austrian based company Beton und Monierbau (BEMO) for the design and field assistance for this work.

TFK presented the client with a new egg shaped profile, immediately supported with shotcrete and rebar following a detailed excavation sequence. Since it had been involved early in the process, the owner quickly approved the solution and supported some of the costs.

The sequential excavation method proved to be very flexible, allowing other work to continue in the tunnel headings. It also allowed for a number of extra measures to be implemented if the ground did not behave as expected.

Design

The cross section geometry was altered to a more rounded structure, allowing for more axial load transfer, improving the structural efficiency of the profile (figure 3).

As is common in Southern California, seismic loads had to be considered. These were assessed in the design by imposing racking deformations onto the external boundaries of the rectangular finite element grid. A combination of 2D and 3D finite element analyses was used to calculate ground loads, water pressure and lining stresses through the construction stages.

The use of chemical grouting (Sodium Silicate) was to minimize ground loss, protect against instabilities, and to reduce groundwater inflow during construction. The required dimensions of the grouted zones were assessed by 3D finite element analyses. Before this, pressure meter tests in the field were performed to quantify the increase in strength and stiffness achieved by the grouting operation.

From the analysis results, possible kinematic mechanisms were identified and corresponding safety margins were determined by evaluating the degree of utilization along the potential failure planes.

The segmental lining had to be supported at each cross passage opening during the cross passage construction. The Internal Tunnel Frame (ITF) system consisted of grade 50 structural steel rings and tie beams, and was installed in both running tunnels, adjacent to the cross passages.

The structurally required lining thickness was calculated using 2D FE-Models. To account for stress relaxation and creep, the hypothetical modulus of elasticity (HME) approach was chosen. The lining consisted of 250 - 300mm of shotcrete with lattice girders and rebar mesh reinforcement. The decision to use welded wire mesh instead of steel fibre was dictated by the need for a sufficiently ductile structure in case of a seismic event.

Extra measures

To address the variable ground conditions and mitigate the risk of delays due to unexpected ground conditions, sets of extra measures were included in the design.

Probe drilling was performed to establish an actual geological and hydro-geological baseline prior to excavation. The information collected was used to determine the need for ground improvement, additional support measures, and/or advanced dewatering.

To prevent stability problems when breaking out the running tunnel segments, and during the first advances, a pre-support canopy formed by a “pipe umbrella” was used for excavation.

Minimal local dewatering, if needed, was initiated within the running tunnels using the probe holes located outside of the excavation profile. Spiling was designed as an optional support measure to be placed where the pipe umbrella would not protect, and where pre-support was needed, and was at the discretion of the NATM engineer.

The sequence of events for mining the cross passages was divided into; probing for gas and water; installation of the pipe umbrella; installation of the internal tunnel frames on both sides; cutting the tunnel liner for “break-in”; excavation/Lining (SEM) in a top-bench sequence; cutting the exit side of the tunnel liner; excavating/Lining the sump if necessary (figure 4).

For the support canopy, pipes were drilled from within the running tunnel before the cutting of the segments. The umbrella consisted of 11 x 90mm diameter pipes spaced out on roughly 450mm centers, in sections totalling 6m. The drilling also provided additional information on the ground conditions at the crown.

As previously described the internal tunnel frames (ITF) consisted of heavy structural beams. The ITFs were designed to relieve the load from the segmental lining during construction, and only after the permanent concrete cross passage structure was complete could the ITFs be taken down.

After installation of the ITFs, the tunnel liner was cut for removal. A subcontractor cut the segments using a wall saw and guide bar. The circumferential joints were simply unbolted prior to removal. Prior to any segment removal, the stage was set for cross passage excavation with all of the necessary tools and equipment required: machine drills, spiling, panning, and all the necessary steel and ground support needed.

The excavation of the cross passages was primarily carried out by a mini excavator, which was extremely versatile in a relatively confined heading. As an alternative to the diesel powered excavator, an electric excavator was on hand in case gassy ground was encountered that prevented the use of a non-permissible excavator.

The cross passage was divided in half, with top and bottom sections. The first step was to remove the top half of the segments with the excavators' detachable hydraulic breaker, then access the ground and apply a flash coat of shotcrete to prevent air slack. Next, section 1 and 2 were excavated to the correct profile, a 50mm shotcrete sealing layer applied, and the first lattice girder and an outside layer of welded wire mesh installed. Following this, a 150mm - 200mm layer of shotcrete was applied; then another layer of welded wire mesh was installed, and a final 50mm of shotcrete.

A third section was then excavated and a second lattice girder installed on top, before excavating and lining the two bottom sections below. Thereby the top is always one step ahead of the bottom. This process continued for the remaining rounds.

Once completed to the opposite side, the segments could be cut and removed and the initial cross passage was completed. If the cross passage had a sump, some additional steps along with rebar were added to reinforce the invert before proceeding to excavate the sump. The sumps were excavated in a similar manner by breaking each step into sections and installing the reinforcement and shotcrete in sub-steps.

Quality

The shotcrete strength development was dictated by the design. However, BEMO's field personnel requested to obtain a "very early" strength (1 minute to 12 hours) that would pass the Austrian Shotcrete guidelines. This was achieved by adding liquid accelerator to the shotcrete water. The accelerator facilitates the bonding of the material to the face, reduces rebound, and allows easier application.

Unfortunately there were contrasting field and design requirements when considering the accelerator: by adding accelerator, the mix texture improves, the very early strength increases, but the later strength (3 and 28 days) drops. The challenge was to adjust the various parameters in order to optimize the quality of the shotcrete. Accelerator percentages of 4 - 6 % were used in order to remain in line with the Austrian Specs, while still meeting the design requirements.

Initially shotcrete panels where shot for quality purposes. Those proved to be cumbersome and mishandling of the panels before the shotcrete had hardened brought some erroneous testing results. BEMO field technicians suggested shooting the panels on top of the existing shotcrete wall inside the excavated crosspassage. A shotcrete "splatter" 1 x 1m, 150mm thick, was sprayed on a section of the temporary support that had been built previously. After testing and cores were taken, the remaining test shotcrete was removed from the wall with a jack hammer. This method gave much better, quicker, and more consistent results.

Challenges encountered

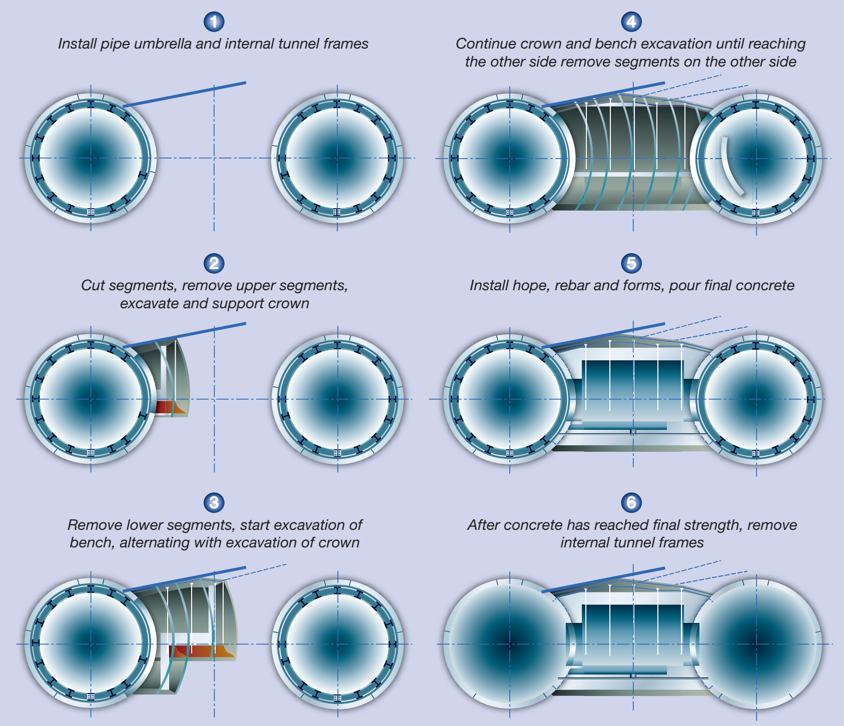
As expected in most part of the Los Angeles basin, gasses were encountered during excavation. A total of three different gases were detected at three different cross passages:

- At cross-passage 1, methane was detected while drilling the probe holes. Adequate equipment (Class 1 Div 2) had to be used. Good ventilation providing, no noticeable trace of methane was further detected
- At cross-passage 4, smelly methanol was present throughout excavation. Good hygiene and ventilation made the work place safe
- At cross-passage 5, hydrogen sulfide was present in the water encountered. Since more serious amounts of water had to be dealt with there, the water was redirected to a "breathing tank" where sodium bicarbonate "teabags" treated the water and good ventilation kept concentrations within tolerable levels

Very different layers of ground were encountered in the same cross passage. This involved water infiltration issues as well as semi-instable soil layers.

At cross passage 1, vast differences between the ground at the top and bottom of

Below: Fig 4 – Cross passage excavation



Above: Sump excavation at cross passage 5 fighting water inflows

the excavation were encountered. The ground on the bottom of the cross passage was more granular than the top and subsequently took the chemical grout much more effectively. The bottom was so hard it required the excavators' hydraulic hammer to penetrate. In contrast, the top of the cross passage contained a very fine layer of material that did not take grout and was subject to sloughing. Beyond the protection of the umbrella, spiling had to be installed and any ground loss replaced with more shotcrete in a controlled manner.

At cross passage 2, the layers identified were practically ungroutable. Together with the grouting subcontractor, TFK decided not to try to chemically grout it. The clayey nature of the layers made it suitable for excavation, although relatively large amounts of water were encountered compared to most cross passes along the alignment. The probe holes were used as drains to relieve water pressure, especially towards the bottom of the sump. This seemed to help reduce inflows and verified that it as perched water within the clays.

At cross passage 5, as soon as the probe holes were drilled, each hole started delivering over 190 l/min. This in addition to the undeniable smell of hydrogen sulfide that accompanied it, caused much concern for TFK's engineers. After verifying the grouting records in detail and probing the various layers at different levels, the engineering team became convinced that the water was originating from a single specific silty layer below the spring line. The silty layer of ground, although permeable to water, would stand long enough to get panning and a layer of shotcrete applied. Excavation took place and crews battled the water using all the tools available.

Drainage was carried out by developing de-watering wells from the running tunnels on both sides of the cross pass. Temporary sumps were installed during the excavation in several locations to provide relief as the excavation and lining were completed.

Conclusion

Construction of the cross passages started in October 2006, and was successfully completed in May 2007. With thoughtful planning and execution, construction was a great success without major incident, or measureable ground loss. The design displayed a great effort between BEMO and TFK, combined with support from MTA. Though not the only way to mine cross passages in soft ground, the sequential excavation method proved a very valuable and flexible practice, and extremely important to the advancement of tunnelling efforts across the world. T&T

The first ever vacuum segment erector?

Above: The open face backhoe for the Three Valleys Water Company tunnel
Left: The original segment erector either dropped or spalled segments

Dear Sir
The first use of a vacuum type erector was on the Thyssen (GB) Ltd tunnelling contract for the Three Valleys Water Company near Heathrow Airport in the UK in 1983. The contract included construction of a 6.2km long tunnel through London Clay and lined with 685mm wide rings of expanded precast concrete segment for a 2.54m internal diameter. Each ring comprised nine ordinary plates or segments, two top segments and a wedge-shaped key at the crown to expand the ring tightly against the clay without any grouting.

An order was placed with Markham of Chesterfield to supply an open-face tunnelling shield with a backhoe excavator, conveyors to discharge muck into rail skips, and a segment erector. This was selected in preference to a fullface rotary type excavator as being the most economical solution for the length of tunnel involved, the planned outputs, and the anticipated ground conditions, which could cause clay to plug the face of a rotary type excavator.

Historically, tunnels of this type and size had been driven successfully using fullface rotary type excavators such as the Kinnear Moodie Drum Digger, but with segments erected manually. The weight of the individual segments on the Three Valleys contract, coupled with the desire to reduce manual labour wherever possible, led to design of a segment transport system to feed a mechanical erector.

The rotary-type erector supplied with the shield had steel claw grippers designed to pick up the segments from the invert and rotate them into position. Unfortunately, and despite some modifications, it quickly became apparent that such a detail would not achieve the planned production rates. The gripper system was either dropping the segment or spalling the edges with increased gripping force. The problems were exacerbated by the different geometry of the ordinary, top and key segments.

Andrew Draper, Thyssen's Agent at the time, recalls that "while sitting in the car at the Datchet level crossing on the way home", it occurred to him that a vacuum lifting device might work.

A quick bit of mental arithmetic based on segments weighing approximately 375lbs and a vacuum force of 12psi, a vacuum pad would require an area of 31in^2. For practical purposes, and with a FOS (factor of safety) of 4, the pad area would increase to 125in^2. (Many engineers at that time would still resort to the imperial system for mental arithmetic and some of the older ones still do!) On arriving home he said: "I jotted down a few calculations that confirmed my original thoughts."

The following morning, he set up a meeting with Thyssen site colleagues Brian Smith, mechanical engineer for the job, Rob James, sub-agent, and Danny Travis, foreman fitter.

Draper recalls, "some, including the manufacturer, were sceptical of the idea." However, it was decided to set up an on site trial. Draper said, "Danny was brilliant and in no time he had canabalised a vacuum pump from an old

Sykes sump pump and had made a crude vacuum pad glued to a curved steel plate using draught sealant. This was rigged up in the site workshop and tried out with the help of a fork-lift truck. Somewhat to the surprise of bystanders, it worked, first time, even with someone standing on the segment!"

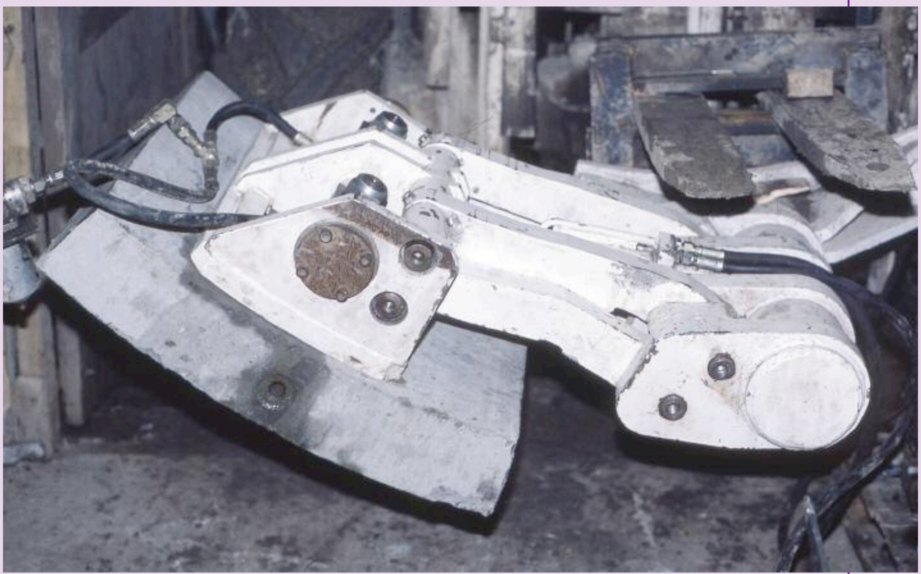
Things moved rapidly from there. In less than a week, the first vacuum erector with site-made vacuum pads was fitted to the shield.

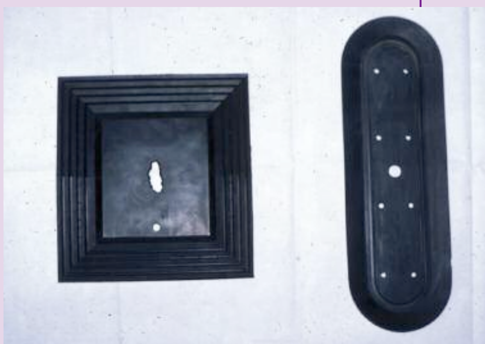
The 'lads' on the machine thought it brilliant. Each segment needed a small hand brush sweep to remove any dirt but unlike the steel finger gripper erector, the vacuum pads did not need locating precisely on the segment and production rapidly reached the target of 25 rings/shift.

Development of purpose-made suction pads had production rates increase further. Following these demonstrations, Markham designed and produced a factory-made product. This enabled frequent production of 40 rings (90ft or 27m) per shift and a best of 54 rings, (122ft or 37m) in a single 12hr shift.

At the time, a patent application was made and subsequently granted naming Andrew Draper and Brian Smith as co-inventors.

Following this application, Markham





Above: **In full swing the new system significantly increased production**
Right: **The purpose made suction pads fitted to the shield**

Below: **The first vacuum erector with site made vacuum pads at work**

developed vacuum erectors for several tunnelling machines in the UK. The first was for Miller Construction (now Morgan Est) for its North London Flood Relief Tunnel in Islington for Thames Water, which was under construction at the same time as Three Valleys. With the patent pending, Thyssen (GB) agreed this license.

In years to come Herrenknecht in Germany picked up and perfected the technique to lift heavier and heavier segments. The first Herrenknecht machine with a vacuum segment erector was also for a UK project. The backhoe shield was manufactured for the Docklands Light Rail tunnel connection to the Bank Underground Station in London in 1988 (see references).

Vacuum segment erectors are now the norm, if not the standard, and are vital for lifting steel-fibre reinforced segments and for building segment rings behind the mega-diameter TBMs being built today. The vacuum erector on the 15.4m Herrenknecht machine on the Chongming under river highway tunnel project in Shanghai for example is lifting segments of 20-22 tonne. Vacuum lifting devices have been used in sheet metal industries and in precast concrete factories for many decades but the multi-tonne segments for a tunnelling job can only be lifted without damage with the wide surface area lift of a vacuum erector.

And it all began as the possible solution to an irritating problem and in the Thyssen (GB) workshop of the Three Valley's tunnel project in the UK in 1983 – unless you know differently?

Yours sincerely
Drifter

REFERENCES

1. Trials and tribulations at Three Valleys - *T&TI*, April 1984, p43
2. Under Three Valleys (BTS meeting report) – *T&TI*, Oct 1984, p55
3. Ground treatment for the Three Valleys tunnel – *T&TI*, Oct 1985, p85
4. Vacuum segment erector speeds mechanised wedge block tunnelling – *T&TI*, April 1986, p41
5. Docklands railway City extension, London – *T&TI*, March 1988, p18

"Drifter" provides a unique opportunity for readers to openly comment on industry issues whilst remaining anonymous. Contact the editor in COMPLETE CONFIDENCE by post or email: Tris Thomas, 'Tunnels & Tunnelling International', Progressive House, Maidstone Road, Sidcup, Kent, DA14 5HZ, United Kingdom; Email: tthomas@tunnelsonline.info

The Arrowhead tunnels challenge

Following the British Tunnelling Society's Annual General Meeting, Brian Fulcher, project director for Shea-Kenny Joint Venture, and Mike Bell, resident engineer for Hatch Mott MacDonald, described overcoming difficult ground conditions and water pressures with two hybrid hard rock TBMs for the Arrowhead Tunnels in Southern California, US

The Arrowhead Tunnels Project is located in the arid region of Southern California, where the average rainfall does well to tip a mere 200mm per annum. The severity of the problem became clear when in the 1930's the state actually ran out of water,. resulting in the construction of the California Aqueduct system, followed by the State Water Project in the 1950's. This is still the region's main source of water, but States upstream have now significantly increasing demands. The Client for the Arrowhead Tunnels Project is the Metropolitan Water District (MWD) which serves 18M people in Southern California over an area of 5200 square miles and delivers 7.5Mm^3 daily.

The project, which includes two tunnels totalling almost 19km, is part of the sizeable Inland Feeder Project that also includes the recently completed Diamond Valley Reservoir, which has a storage capacity of 1bnm^3 of water.

Construction of the two tunnels comprised 12.9km of 5.8m diameter bored through hard rock by twin TBMs near the base of the San Bernardino Mountains and passing within a kilometre of the world renowned San Andreas Fault and crossing numerous other significant faults (figure 2).

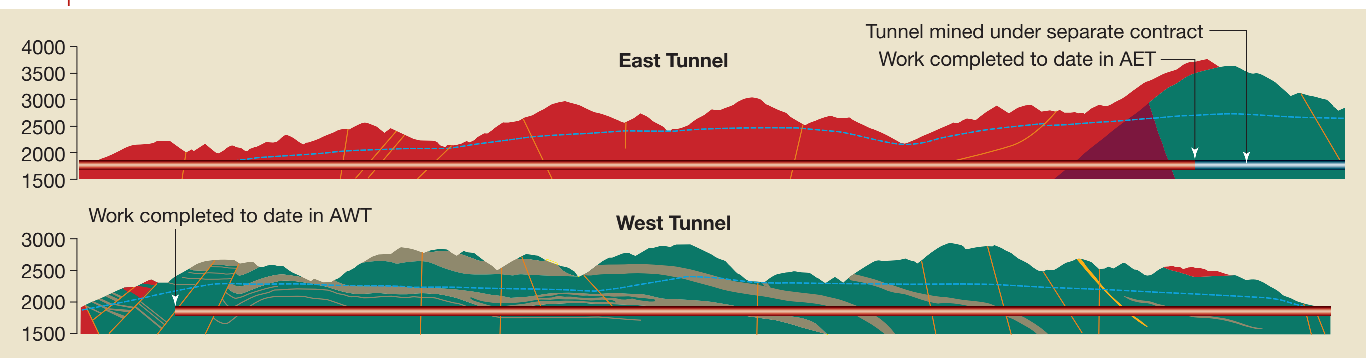
Ground conditions along the alignment vary extensively from highly fractured to massive, moderately jointed igneous and metamorphic rocks with faults and shear zones. Water pressures in the tunnel area are also significant reaching up to as high as 20 bar.

Construction commenced on-site in 2002 and is due to be complete in 2009. The initial bid value of the project was US$242m. Construction Managers for the project are Hatch Mott MacDonald, with design support provided by Jacobs Associates. The contractor is a joint venture of Shea/Kenny.

At the BTS meeting Mike Bell, resident engineer for Hatch Mott MacDonald gave an overview of the project and Brian Fulcher, project director for the Shea/Kenny JV presented some of the significant problems and challenges as well as successful solutions implemented on the project.

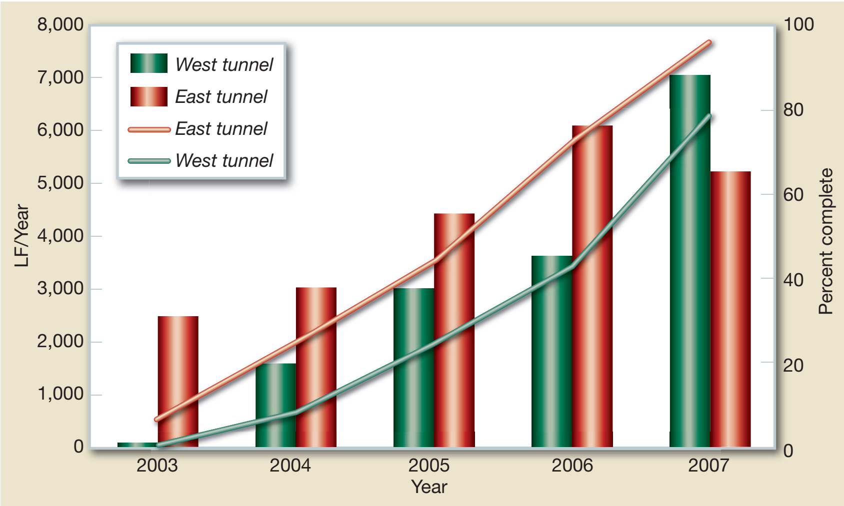
Left: Fig 1 – Location of the Inland Feeder Project and Arrowhead Tunnels

Below: Fig 2 – Geological profile of tunnels



Above: Flooding of the Waterman Portal

Right: Fig 3 – Annual tunnel production



Project history

The Arrowheads Tunnel project first started well over a decade ago back in 1994, with a construction contract awarded to Shank Balfour-Beatty in 1996. At that time junk segments were used for the tunnel construction, these had no gaskets, but were grouted. High water inflows of up to 100 l/s were encountered which affected both the area's vegetation and the San Manuel Indian Tribe who were bottling and selling extracted water from the aquifer. An injunction was served and construction immediately stopped in 1999. The length of tunnel constructed during this first contract is shown in grey on Figure 1.

The project was resurrected shortly afterwards and went through a re-design between 2000 and 2002, this time with previous water problems in mind, with a fully gasketed and sealed segmental lining. To re-start construction a United States Forest Service (USFS) Special Use Permit was required; this limited groundwater inflows into the tunnel, records of which had to be posted regularly on the internet.

The second construction contract was awarded to the Shea/Kenny JV in 2002 with tunnelling re-commencing in August of 2003.

Challenges and milestones

Some of the major challenges encountered included the variable ground and water conditions (figure 2). Substantial groundwater pressures of up to 270m were predicted. In addition, the alignment crossed active geological fault zones; five identified zones on the East Tunnel and 17 on the West Tunnel, along with many smaller unidentified zones. The USFS also had review and oversight of the construction to ensure compliance with the groundwater inflow limits specified in the USFS Special Use Permit. The San Manuel Indian Tribe also had oversight for the East Tunnel to ensure their water business remained un-affected by construction.

In addition to variable ground and high groundwater pressures there were two major forest fires in 2003 and 2007 in the Lake Arrowhead area that shut down the site for days. To pour further hardship on the project, following the forest fire in 2003, a landslide caused by heavy rains flooded the Waterman Portal, then fully submerged the TBM and shut down the job for four months.

As of the end of April this year, the Arrowhead Tunnels are virtually finished with 96% complete; the East Tunnel is fully bored and the West Tunnel is currently 91% complete. Over 6130M tonnes of cement grout has been injected for both water control and ground improvement, this has allowed the works to comply with the stakeholder requirements.

The tunnel production rates have

Right: Water inflows in the tunnels

Below: Screw auger 'bone yard'

Above: Pic 4 – Hand mining over the shield

increased year on year throughout the job as more was learnt about the ground conditions (figure 3).

The remaining 650m of tunnel will be just as challenging as the completed kilometers, with its highly variable geology, ever decreasing cover, constant groundwater issues, and a 90° curve.

Water inflows and pre-grouting

Groundwater flows and pressures if not controlled can be substantial and can quickly curtail mining operations. In practice up to 70% of the time spent in the tunnel was spent grouting, as to mine successfully the groundwater must be well controlled.

In good ground conditions the probe length was approximately 150 feet (45.7m), in order to mine 130 feet (39.6m) and leave a 20 feet (6.1m) buffer. In stretches of poor ground the solution was found to be to combine drain holes for pressure relief, to decrease the pressure gradient, with pre-excavation grouting with between 19 and 31 holes in small cycles to improve both grouting and mining conditions. BASF assisted with field testing of their MP320T colloidal silica grout, designed to penetrate tight strata to control water inflows that could not be stopped with the use of micro-fine cement grout.

TBM and squeezing ground

Both 5.8m diameter hybrid hard rock TBMs were built by German manufacturer Herrenknecht and are true one-offs. The TBMs were among the highest specification machines ever when they were originally ordered, and certainly the highest spec to have been used in the US. The TBMs featured; cutterheads that could articulate up to 152mm, a shroud on the trailing edge of the cutterhead for improved ground control, two percussion drill decks, a casing advancing system for drilling probe and grout holes in poor ground conditions, screw auger wear plate improvements, an improved one-of-a-kind slurry handling and separation system, a vacuum segment erector (the first of its kind in the US) and a data-logger for ground assessment while drilling. The TBMs were designed for up to 10 bar of groundwater pressure, less than the full groundwater pressure.

Each machine used a total of six augers. It was originally envisaged each machine would only require one auger, so the 14m long auger was redesigned into a 4-piece auger which took 3-4 days to assemble within the TBM.

One of the biggest improvements on the job was the data logging on the probe drill holes, which provided a 'crystal ball' view of what was ahead. But even still the TBM got caught in squeezing ground three times while driving the East Tunnel. This meant having to hand mine over the shield three times to free the TBM from the squeezing ground which was successfully completed on each occasion.

The lining

The 4,880mm internal diameter segmental lining had a thickness of 330mm which was thick for this diameter, but this was due to the design groundwater pressure. Due to the squeezing ground up to four times the original design thrust was applied to the segments, so the thicker lining meant this was also possible. The single Phoenix (profile M 385-73) gaskets were tested to 40 bar pressure, although were designed for 27 bar pressure. The primary support of the segmental lining will have a final 12 foot (3,658mm) diameter RCCP tunnel lining installed inside, with the annulus backfilled with grout.

The Arrowhead Tunnels have put the project teams through a host of challenges and could be regarded as amongst the most difficult tunnels in the world to date. It is a credit to all involved that they have not been consigned to the too difficult to build list. T&T

QUESTIONS FROM THE FLOOR

Mike McCall (retired, formerly Balfour Beatty) asked about the method of payment related to minimising inflows to the set requirements and secondly who paid for all the grout. Brian Fulcher noted that there was no penalty for not achieving the inflow rates. Mike Bell added that not all the grout that went into the ground was paid for, there were serious negotiations between the client and the contractor, but the commercial terms remain confidential, there is now a partnership between the client and contractor though.

Tim Healey (Capita Symonds) asked with the close proximity to the San Andreas Fault what allowance had been made for earthquake risk in the seismic design of the tunnel. Brian Fulcher remarked that if there were a rupture of the feed the water would be captured in distilling basins located along the alignment. Mike Bell also noted that the lining pipes were formed of 10" (254mm) concrete 0.5" (13mm) steel with then a grout annulus to the segmental lining.

Phil Richardson (Natural Cement) asked whether there were any environmental concerns over grouting noting that San Manuel Indian Tribe were selling bottled extracted water. Mike Bell noted that both the San Manuel Indian Tribe and USFS had to approve the grout before it was used.

Shani Wallis (Journalist) asked how much original SI had been allowed compared to the SI for the second contract and secondly how accurate was the GBR found. Brian Fulcher remarked that the SI for the east tunnel was comprehensive, but this was for a different alignment, the SI was extended for the new alignment, but was not as comprehensive. Mike Bell added that the GBR did quite a good job of describing the conditions, it picked up the big faults, but it was the small unknown faults that caused a lot of the problems. The GBR did warn of the groundwater inflows.

Noel Harrison (Mott MacDonald) asked what proportion of time was used for drilling and grouting and secondly what production rates were achieved. Brian Fulcher reported that production rates were highly variable, on a good day 25m per day, on a bad day all day could be spent probing and grouting. Mike Bell added that on a good day ring excavation could occur in 30-35min, with rings built in 20-25min. Production rates were very hard to predict, but the probe drilling proved extremely useful.

Colin McKenzie (semi-retired) asked what rock strengths were being dealt with as he was surprised that very little cutter wear had been reported. Brian Fulcher agreed that there was very little cutter wear in both tunnels. The maximum rock strength was around 20,000psi (140MPa).

David Sharrocks (London Bridge Associates) asked what the build-up of the tunnelling crew was. Brian Fulcher quickly responded that he did not think this was a question that a contractor should answer. Paul Hoyland then thanked both speakers for an excellent honest presentation and wished the project success for the final few hundred metres of the drive.

Raporteur: Nathan Wilmot

Collaborations for complex casting

A Marti Technics invert formwork unit awaits use on the Moutier Tunnel, in Switzerland

The equipment adopted for the in-situ casting of tunnel linings can have a major impact on overall project cost and time schedules. Amanda Foley, deputy editor, looks at three recent case histories

Demands on the performance of modern cast in-situ tunnel linings are more stringent than ever. This can be demonstrated alone by the fact that many of the underground structures currently being built around the world are so structurally complex and technically challenging that their realisation would have been inconceivable even just a few decades ago.

Regardless of the size of the project however, any durable cast in-situ final lining that is designed to minimise direct and indirect maintenance costs and handle all anticipated conditions throughout the design-life of the infrastructure, will need to take into consideration numerous factors.

These may include external or internal corrosion, static or dynamic ground loading, water control measures, internal impact and/or fire in transport tunnels, and internal pressures in hydropower, water supply, and sewers. Concrete mix design (including curing times, and a balance between early age and long-term strength), selection and design of the concrete forms, the logistical interaction of plant and equipment within the tunnel, pumping distances and pressures, as well as ever more demanding cost and time-schedule constraints, all also need to be resolved.

Leading tunnel formwork manufacturers and suppliers are doing their best to assist in meeting some of these challenges, working with tunnel designers and contractors to refine designs, increase standardisation and dimensional flexibility of formwork components, improve handling processes, and reduce both the capital and running costs of the equipment.

Minimising labour intensive operations involved in, for example, transportation phases, erection and disassembly, adjustments and placement, have been greatly reduced by the development of self-retracting and/or mobile forms. The need for highly-experienced operatives has also been greatly reduced with automated vibration and concrete pumping systems.

Left: Ceresola TLS recently supplied two bespoke self-travelling forms to the Kiewit Pacific JV for the Devil's Slide project, in California, USA

Complex cavern concreting

One of several recent 'mega' projects to require challenging and extensive concreting works was Austria's Kops II project, which includes one of the world's largest rock caverns, a 90m long, 30m wide and 60m deep powerhouse.

The Jäger Bau/Beton-und Monierbau/Alpine Mayreder/Züblin JV, completed the excavation works on its Lot 3 contract - consisting of the powerhouse, a transformer cavern and associated tunnel systems - between November 2004 and December 2005. Following this, working to a fierce schedule and pushing site logistics to the limit, approximately 48,000m^3 of concrete was cast within the caverns over a period of just 18 months.

This was concurrent with the numerous lining and backfilling works in the project's tunnels and shafts, as well as hydro-mechanical equipment installation.

Forming concrete slabs of up to 8.5m in height, with thicknesses varying from 200mm to 4m, for the project's caverns placed enormous demands on the flexibility of the formwork system used. Another vital aspect of the works was the intensity of logistics in the powerhouse, which required the stock of formwork components to be reduced to an absolute minimum.

Eventually a comprehensive concept for the erection of the massive reinforced concrete walls and slabs was provided by German formwork specialist Peri. Using standardised Peri TRIO formwork panels, which utilise a single connection for all element joints and use few components, adjustments and modifications for the different lining sections, with numerous box outs and reinforcement connections, were carried out quickly and efficiently.

Due to the large quantities of concrete required in the caverns and the expected high temperatures, the original intention at tender stage was that concrete pumping would not be used. However, the plan to place the concrete using crane and skip was soon ruled out. This was due to the fact that the commencement of the lining works coincided with the installation of the hydro-mechanical equipment, meaning very limited availability of the powerhouse's auxiliary crane.

Instead, two Putzmeister concrete distribution booms were employed to reach all parts of the cavern and a pumpable concrete mix was developed, modified and adjusted several times, to keep the temperatures low and minimise shrinkage cracking. An in-situ concrete mixing plant was also installed on site to allow independence and flexibility of supply.

The construction sequence was arranged so that the assembly, installation and concreting works were carried out in a staggered approach between the generating unit locations. For single-face concreting, Peri's TRIO panels were used together with brace frames in order to safely transfer the fresh concrete pressure into the sub-structure. The modular brace frame units were coupled for concreting heights up to 8.5m without requiring accessories.

The loads resulting from the 4m thick walls were correspondingly high, but during the concreting works were safely carried by Peri's ST100 stacking towers and Multiprop aluminium slab props. These lightweight individual components, along with a simple assembly process, proved to be particularly advantageous in planning and reduced the need for time-consuming static calculations.

In areas of large load concentrations, Peri's HD200 heavy-duty props supplemented the shoring concept. Also frequently used in bridge construction, the aluminium prop sections have an enormous load-bearing capacity (200kN) with low individual weights.

For scheduling reasons all other lining works on the contract also had to be completed at the same time as the lining works for the main powerhouse cavern. Works in the transformer cavern were scheduled to compensate for interruptions in the powerhouse, primarily during equipment installation, while for the reinforced concrete lining of the tunnels a Peri tunnel formwork carriage was used.

For some concreting sections of the surge tank a continuously adjustable Peri RUNDFLEX circular formwork was used without anchors. Instead, loads from the distribution walers were transferred to a central core through heavy-duty spindles.

Self-retracting in Spain

Overcoming the extremely complex logistics and tight space constraints at Kops II, by using simple and effective standardised components, was key to the successful completion of the demanding lining works, within an extremely tight project schedule.

However, the major trend seen in recent years has been the move away from labour intensive operations involved in the placement, erection and adjustment of formwork. Some of the largest self-retracting steel forms used to-date in Spain were recently employed by the UTE La Herradura JV, on three twin-tube highway tunnels, which form a major part of the Mediterranean Highway scheme between

Right: Extensive casting operations underway in Austria's Kops II HEP cavern
Below: One of the two CIFA units used by the UTE La Herradura JV, in Spain

Above: **Mammoth concrete pours underway at Kops II, utilising Peri formwork units**

Cadiz and Barcelona.

Following drill and blast excavation of the 12.5m wide twin Cantalobos, Calaceite and Gato tunnels, which total 2.7km in length, the JV adopted twin 15m long CIFA forms to cast the final linings. The units came complete with an integrated wall vibration system and a CIFA DCL 750 automated concrete distributor.

Due to multiple curves and counter-curves in the alignments and a consistent variability in height, the use of self-retracting forms with adjustable articulated struts was selected over traditional anchored forms in order to reduce the time and labour that would have otherwise been required to deal with the variable geometry.

In particular, the need for continuous and precise overlap adjustment of the arch form on the kicker and time required for anchor installation would have had a big impact on schedule, "and could have lead to the risk of higher deformations on the longitudinal joint," says Eugenio Bertino, head of CIFA's tunnelling formwork division.

With a maximum casting rate of approximately 8 hours and a minimum curing time of 12 hours, concreting of each 15m long shutter section was performed in a prolonged single shift, with six 15m casts undertaken each week.

For the shorter Calaceite (278m) and Gato (220m) tunnels a single form was employed for each twin bore. On the longer Cantalobos tunnel (2170m) the two forms were used in parallel, achieving 4.3km of completed lining in just eight months. "These are considerable performances considering the complicated geometry and the long curves present," states Bertino.

Once the main lining works were finished, one of the formwork units was modified in order undertake the lining of four 40m long widened tunnel sections that had been constructed as emergency parking niches. In order to configure the unit, elements from the original formwork structure were reused and a 2.2m wide 'key' added into the crown of the unit to create the wider profile.

For ease of transport and repositioning of the form between the parking niches, the entire unit was built onto a truck-mounted hydraulic "turret". The use of this solution provided considerable reductions in overall capital equipment investment and job-site labour costs, as well as providing the contractor with the opportunity of future reuse, or even rental, of the "turret" transportation device.

Rentable solution in Trondheim

Along with the development of standardised formwork components, there has also been much growth in the rental market. One such example is a highway tunnel currently under construction in Norway. As part of the E6 northern relief-road project in Trondheim, a high-capacity bypass is being built to skirt the harbour area. Scheduled to open to traffic in 2010, the new bypass will alleviate traffic congestion in the city-centre. Part of this bypass will run through a tunnel 10m beneath sea level.

The 505m long tunnel is being built by Bilfinger Berger using two fully rentable travelling formwork units from Doka. The units are based on standardised rentable system components, and are fitted with Doka's FF 20 wall formwork and 3-SO formwork sheeting.

The construction trench is inside a sheet-pile cofferdam with walls up to 16m high. Following completion of the in-situ casting of the concrete base slab, the tunnel walls and the cover-slab are poured in a single operation using the Doka travelling formwork units, in 12.5m long sections that are cast in a weekly cycle.

After each casting section has been completed, the entire formwork unit is transported via rail to the next casting section. Varying by up to 2m in both height and width, the tunnel cross-section has placed high demands on the formwork in terms of adaptability. Therefore interchangeable and compensating elements are incorporated to ensure precise, rapid alterations.

Casting collaborations

Although three very different projects, each demonstrates the importance of partnerships between project teams and manufacturers. Early involvement of suppliers in the planning process can often provide invaluable solutions to site specific problems, or simply assist in the reduction of project costs. T&T

Right: **Doka's travelling formwork units at work in Trondheim, Norway**

Classified

RECRUITMENT

Hunter Personnel

Specialists in Tunnelling, Civils and Construction Recruitment.

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

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

www.hunterpersonnel.com

UK & OVERSEAS OPPORTUNITIES

V-Engineering Recruitment

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

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

Construction Manager (Tunnelling)

Location: London - Freelance or permanent - Salary: Negotiable

Required for main blue chip contractor based in East London.

This £40 mil. Project consists of:
- 2 km of "live" online pipeline upsizing and numerous new manholes all completed within the busy streets.
- 3km of 2.87m diameter tunnel through mixed ground (Lambeth Beds) using a new full face TBM.
- 5No. tunnel shafts, including a major pumping station, all in water bearing ground using both the caisson and underpinning method.
- 2.5km of 1200mm microtunnel, using slurry TBM's.
- 19No. Microtunnel shafts.

Senior Engineers (Tunnelling)

Location: London - Freelance or Permanent - Salary: Negotiable

Required for large blue chip main contactor based in East London. The right candidate's main responsibilities will be:
- Review Quality control and implement best practice.
- Apply health and safety regulations.
- Explain critical path work for the section or project.
- Revise information with designers and project team regularly.
- Supervise and review performance of team members.
- Prepare risk assessments and method statements.
- Oversee setting-out and checking of setting-out.
- Reviewing drawings/method statements and passing information on to the Site Supervisor and/or labour force.
- Prepare and present reports on progress and programme.
- Monitoring subcontractors including reviewing their Method Statement and Risk Assessments.
- Developing and update sectional programme in line with main construction programme.
- Check schedules against drawings, liaising with designers over changes.

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

International Tunnelling Services
Professionals in tunnelling

With teamwork to the breakthrough.

Are you looking for experienced personnel to work on your tunnelling projects?
We are specialised in tunnelling recruitment solutions. We are able to supply qualified personnel of all levels, from back-up labour to project manager.

Experienced personnel of different nationalities.

Do you require an efficient, prompt and accurate solution to your recruitment need?
Please contact us to discuss your requirements.
E-mail: info@tunnelcrew.nl

www.tunnelcrew.nl

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

COYLE Personnel Plc
Recruitment Specialists

Construction Manager – London – to £50K + Subsistence + Car & Benefits

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

Geotechnical Engineer – UK – to £47K

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

Graduate Engineer – UK – £28K + Benefits

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

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

Experienced Site Engineers to supervise site works on major tunnel construction.

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

www.coyles.co.uk/tunnelling

Do you have a vacancy to fill or some equipment to sell?

Call: Gary on +44 (0) 208 269 7849
Email: gtween@tunnelsonline.info
Fax: +44 (0) 208 269 7840

WEBSITE DIRECTORY

ACI ALWAG
DSI SOPROFINT DSI
DYWIDAG-SYSTEMS INTERNATIONAL
GROUND CONTROL SOLUTIONS
www.dsi-tunneling.com

MINOVA
Minova CarboTech GmbH
Waterproofing - Consolidation - Bolting
Phone: +49 201 172 1038
Fax: +49 201 172 1317
Email: info@minova-ct.com
www.minova-ct.com
www.minovainternational.com

PALMIERI
TUNNELLING - DRILLING
CUSTOM-MADE CUTTERHEADS FOR TBMs
MICROTUNNELLING AND VERTICAL OR DIRECTIONAL DRILLING MACHINES.
BACK UP AND MUCK HAULAGE SYSTEMS.
ROLLING STOCK AND SPECIAL TUNNELLING RELATED EQUIPMENT.
PH. +39 0565 857127
FAX + 39 0565 856152
sales@palmierirocktools.com
www.palmierigroup.com

H_2OX
• Leak Sealing • Soil Stabilisation
• Structural Reinforcing • Ground Water Control • Disaster Recovery
OXFORD HYDROTECHNICS
Tel: +44(0) 1869 346 001
info@h2ox.net
WWW.H2OX.NET

Sp SPECIALIST PLANT
TUNNELLING EQUIPMENT HIRE & SUPPLY
Specialist Plant Associates Ltd
Agents for CIFA
Tel: +44(0) 1234 781 882
Email: info@specialistplant.co.uk
www.specialistplant.co.uk

Tunnel, Caisson & Cavern
TPC Tunnel Software
BABENDERERDE ENGINEERS
Worldwide engineering service with experience in all types of geology and construction techniques
♦ Design Assistance
♦ Consulting
♦ Construction Management
♦ Technical Assistance
Germany, USA, Brazil
www.babeng.com

DTS
DESIGN & TECHNIC SINGAPORE
Total Tunneling Solution
10 units of Used Schoma Locomotives Available
(Model: CFL-180-DCL & CFL-200-DCL)
T: +65 6515 1970
F: +65 6515 1971
Email: info@d-t.sg
www.d-t.sg

SCHAUENBURG
TUNNEL-VENTILATION GMBH
Flexible Ventilation Ducting
www.tunnel-ventilation.de
Phone: +49 208 8827610
Fax: +49 208 8827615

MASCHINEN- UND STAHLBAU MSD DRESDEN
NIEDERLASSUNG DER HERRENKNECHT AKTIENGESELLSCHAFT
Your partner for special solutions in the tunnelling sector.
Phone: +49 (351) 42 34-0
Fax: +49 (351) 42 34-103
E-Mail: info@msd-dresden.de
www.msd-dresden.de

ALAN AULD ASSOCIATES
DESIGNERS CONSTRUCTION CONSULTANTS
TUNNEL AND SHAFT SPECIALISTS
Telephone +44(0) 1302 329911
Fax +44(0) 1302 329922
Email mail@alanauld.co.uk
Website www.alanauld.co.uk

The one-stop source for the tunnelling industry.
It's only a *mouse click* from here!
tunneltrade.com
your tunnel internet portal

ABG
ENVIRONMENTAL GEOSYNTHETICS
CAVIDRAIN
Groundwater Drainage for Tunnel Walls & Invert
T: +44(0) 1484 852250
F: +44(0) 1484 354825
E: export@abgltd.com
www.abgltd.com

TRANSFORGE UK LTD
Tunnel Steelwork Specialists
Cable & Pipe Brackets and Walkways
Sleepers and Accessories
+ 44 (0) 1572 787 504
info@transforge.co.uk

Geotechnical Instrumentation
Products for monitoring tilt, displacement, pressure, and strain. Data acquisition and remote, web-based monitoring systems.
SLOPE INDICATOR
www.slopeindicator.com ● solutions@slope.com
Tel: +1-425-493-6200
DGSI
DURHAM GEO SLOPE INDICATOR

QA PHOTOS
'Experience in depth'
Tel: +44 (0)1303 894141
Fax: +44 (0)1303 894144
Email: pix@qaphotos.com
www.qaphotos.co.uk

HERRENKNECHT
Tunnelling Systems
www.herrenknecht.com

WWW.LOVAT.COM

H+E LOGISTIK GMBH
www.helogistik.de

VMT
www.vmt-gmbh.de

tunnels & tunnelling INTERNATIONAL
www.tunnelsonline.info

Advertise on this page from only £50.00 per month
and target 14,000+ tunnelling professionals every single month - including the 900+ BTS members
No other tunnelling magazine delivers a readership of this quality
Tunnels & Tunnelling International - the only dedicated monthly international tunnelling magazine
Contact Gary on Tel: +44 (0)20 8269 7849 Email: gtween@tunnelsonline.info

Dates & Events

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

08-10 SEPTEMBER
Underground Spaces 2008 New Forest, UK
Organised by the Wessex Institute of Technology and the National Technical University of Athens, this conference focuses structural and material character-isation and trends regarding the utilisation of underground space. Contact: enquiries@wessex.ac.uk; web: www.wessex.ac.uk/conferences/2008/underground08/index.html

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

10-12 SEPTEMBER
Breakthroughs in Tunneling Golden, Colorado
The Colorado School of Mines, in conjunction with Tunnel Business Magazine and Microtunneling Inc, presents a Short Course that will cover all aspects of conventional and mechanised tunnel design and construction in hard rock, soft ground and soils. Presented by international experts. Contact: timcoss@microtunneling.com; web: www.tunneling.com

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

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

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

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

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

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

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

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

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

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

BRITISH TUNNELLING SOCIETY

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

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

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

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

A DATE TO REMEMBER...

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

Contacts

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

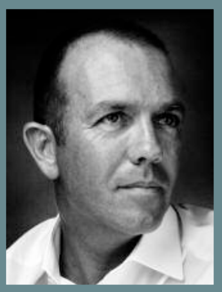
WEB
www.tunnelsonline.info

TEL
+44 20 8269 7789

FAX
+44 20 8269 7840

Tris Thomas

Amanda Foley



Gary Tween

David Wildman

HOW TO CONTACT US

EDITORIAL

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

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

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

DESIGN
Natalie Kyne

TECHNICAL ILLUSTRATOR
Nick Stenning

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

ADVERTISING

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

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

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

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

PUBLISHING

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

HOW TO SUBSCRIBE

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

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

HOW TO GET BACK ISSUES

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

HOW TO GET REPRINTS

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

REPRO/PRINT

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

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

POSTMASTER: send address corrections to Tunnels & Tunnelling International c/o BTB Mailflight Ltd, 365 Blair Rd, Avenel, NJ 07001. US agent: BTB Mailflight Ltd, 365 Blair Rd, Avenel, NJ 07001.

BTS - EDITORIAL ADVISORY BOARD