FEBRUARY 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON EUROPE

This month's focus includes an in-depth report from Austria's Lower Inn Valley HSR tunnels

TRENCHLESS TECHNOLOGY

T&TI's regular look at trenchless technology and techniques

01.08 E

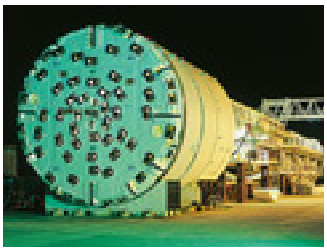
SPAIN: TWIN BREAKTHROUGH.

The way is open: Two Herrenknecht tunnel boring machines successfully excavated the Perthus Tunnel by the end of 2007. The two parallel, 8 kilometer long tunnels under the Pyrenees form the core section of the high speed railway route between Figueras and Perpignan along the Spanish-French Mediterranean coast.

The construction site team used two identical Double Shield TBMs to excavate the Perthus Tunnel. With a diameter of 9.9 meters each and a performance of almost 5,000 kW, they cut their way through granite, gneiss, granodiorite and slate starting in August and October 2005 respectively and delivering constantly high performances. The top record was 193.5 meters in one week. A result which once again proves Herrenknecht's expertise in hard rock drilling.

LE PERTHUS | SPAIN

PROJECT DATA	CONTRACTOR
S-286, S-296 **2x Double Shield TBMs** Diameter: 9,900mm each Driving power: 4,900kW each Tunnel lengths: 2x 8,195m Geology: granite, gneiss, granodiorite, slate	Túnel del Perthus A.E.I.E., Dragados, Eiffage



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Contents

FRONT COVER:
Lining works underway at the Kops II Pumped Storage Plant, in Austria. The project boasts one of the largest rock caverns in the world (p22).

WEB ADDRESS
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CONVERSIONS
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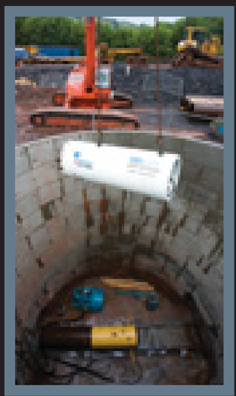
16
Sub-aqueous open cut tunnelling for the Lower Inn Valley HSR

34
Construction of the Dounreay Interim Level Waste Shaft

42
Microtunnelling for the Milford Haven Gas Pipeline Project



Right option first time...

It is interesting to read, in the opening feature this month - 'Brenner's gearing up' - that, on reflection, the 13m o.d. single-tube, twin-track high speed rail tunnel that is being built on the Lower Inn Valley upgrade to design principles from the 1980's and 1990's, could have been very different if built to a more modern design.

General manager of the project, Johann Herdina, believes substantial savings could have been achieved if the route had been designed as a smaller diameter twin-tube configuration. The larger single-tube has proved considerably more expensive, mainly due to the fire life safety and evacuation facilities needed, including long parallel safety tunnels and extensive shafts.

This has been in evidence on the current 40km long Phase 1 of the Lower Inn Valley upgrade, 80% of which is underground, and is already having repercussions on the future construction of Phase II. Phase II is 22km long, but as opposed to Phase I, it is hoped that only 50% will need to be underground.

It seems a shame that the high costs associated with tunnelling could be forcing the line above ground. Would this be the same had the tunnels been built as a cheaper twin tube configuration, linked by cross passages?

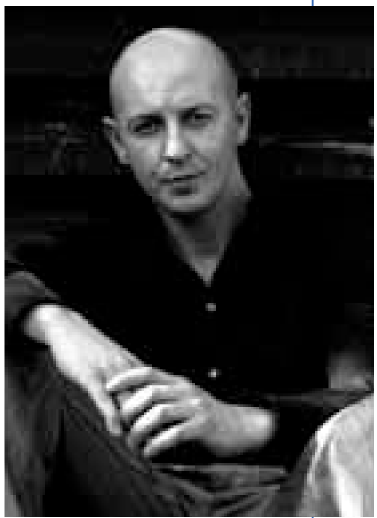
One possible solution being considered for Phase II is to place high-speed freight rail underground with the less rigorous fire safety standards required, and the passenger lines above ground. This seems to completely defeat the point of building a tunnel in the first place!

I really do think these sort of basic design and cost issues need to be ironed out as a matter of extreme urgency, or they could represent a real threat to clients considering underground options.

High-speed rail networks, and their many hundreds of kilometres of tunnels, are picking up impetus and are beginning to become a serious transport alternative to roads and airlines. Just look at the Eurasian Land Bridge, an ambitious plan to link Paris and Tokyo by high speed rail, via Berlin, Russia, China, Pyongyang and Seoul.

If we want tunnels to be a viable and intrinsic element of the world's future transportation systems, it is imperative that the correct design is promoted and adopted on any given project. There are enough hurdles in the way of the underground option already, lets not create any more of our own.

Tris Thomas



COMPANIES IN THIS ISSUE

Stockholm sees rush of tunnels for road...

A burst of road tunnel contracts totalling US$427M were awarded last month for the northern bypass (Norra länken) project in Stockholm by the Swedish Road Administration (Vägverket).

The biggest contract value of almost US$122M was awarded to the joint venture of Germany's Hochtief and local firm Oden for the NL35 rock tunnel. The contract, at Värtan, involves 400,000m^3 of excavation.

The JV was also awarded a contract of almost US$70M for the NL51 section of the bypass, also at Värtan, which involves construction of a concrete cut and cover stretch of road tunnel.

Two contracts were picked up by Norwegian firm Veidekke to build rock tunnels on the NL33 and NL34 sections of the project for US$73M and US$98M, respectively. The NL33 section is at Albano and involves approximately 250,000m^3 of excavation, and the NL34 section at Teknikhöjden calls for approximately 300,000m^3 of excavation.

The four contracts follow the award of a US$64M job to Skanska to build a combination of rock tunnel and a section of concrete cut and cover tunnel on the N11 section at Karolinska. Approximately 50,000m^3 of excavation is required for the rock tunnel portion.

Norra länken will see 11km of tunnel constructed in total with 9km in rock and 2km in concrete cut and cover, and 90 emergency exits.

Atlas Copco boomer on the Norra länken bypass, Stockholm

Separately, other contractors that have been involved in contracts for the preparatory works and access tunnels include Bilfinger Berger and Oden, for which Atlas Copco boomers have been used.

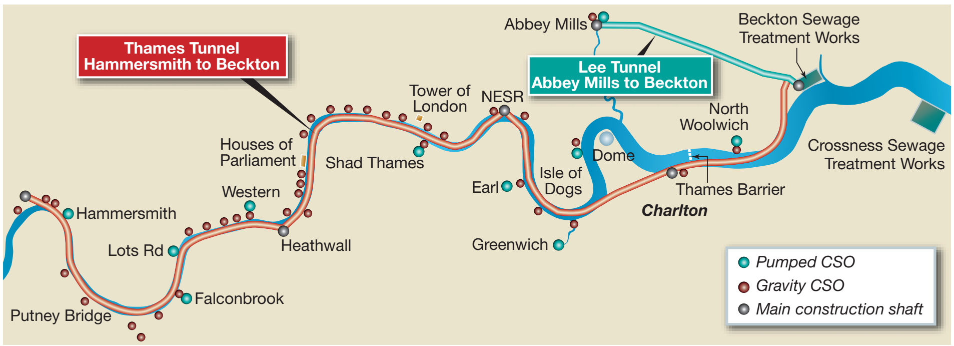
...and immersed tube for rail

A contract to build an immersed tube tunnel in Stockholm has been awarded to a joint venture of Ed Züblin and local firm E Pihl & Son by Banverket, the Swedish Rail Administration.

The 370m long immersed tube will be executed on the rail project on a design and build basis by the JV for approximately US$200M. The tube will be in the southern section of the link in the Fjarden river between Riddarholmen and Sodermalm.

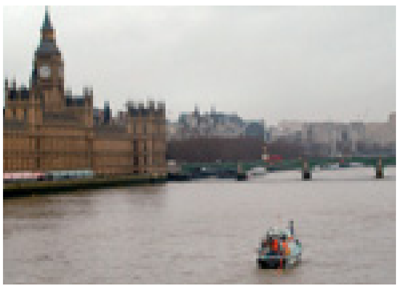
As part of Banverket's 6km long City Line (or "Citybanan") double track link which will be built entirely in tunnel, the immersed tube will be a key element in de-bottlenecking the rail capacity in the capital.

The project has been under development for more than two decades, has a total budget of US$2.5bn, and is due to come into operation in 2017. Two new stations – Station City and Odenplan with extensive excavation for a network of passages plus drill and blast drives for the twin bore running tunnels are key features in the project. Züblin and Oden have been opening an access tunnel. Consultants include WSP Group.



Above: Layout of the Tideway scheme, which will run mostly under the river Thames

Right: The acoustic survey vessel passing Parliament during last month's Tideway site investigation work



Thames deep survey for Tideway

A geophysical survey of much of the river Thames was completed last month by joint venture of consultants OtB Engineering and Cerida Consulting for the main stretch of the proposed Tideway sewer interceptor project.

Contractor EGS International performed the seismic profiling for the JV using its inshore research vessel "Wessex Explorer" and completed more than 160km of survey in four runs over two days. Two different acoustic sources were used for the survey. More surveys are planned for mid-year.

The 32km long, 7.2m i.d. Thames Tunnel section of the scheme is to be excavated by TBM at depths of 30m-70m. Work is to start mid-2012 and finish mid-2020. The separate, 6.8km long Lee Tunnel spur will be deepest at up to 75m. The US$4.5bn scheme to collect overflow discharge from heavy rain has a period of 2007-2020 (*T&TI*, December 2007, p32).

NFM shield completes first Wuhan drive

China Railway Tunnel Group last month completed the first drive on the twin bore road tunnel below the Yangtze river at Wuhan, Hubei province, with a 11.38m diameter NFM Technologies' slurry TBM.

The second, identical TBM is expected to hole through on the parallel drive at the end of February, having started its 2.7km long drive just under a year ago. Then the first TBM had advanced less than 10% of its drive.

Excavation had been expected to be completed about the end of 2007 but the TBMs have been able to perform their drives without the need to change disc cutters or drag bits.

The machines were fitted with bucket and face scrapers from TunnelTec in the first use of its tools in China.

NFM noted that such replacement work could have required hyperbaric operations as 1.7km of each drive was in critical geological conditions with pressures up to 7 bar.

Tunnel boring was through silt and sand with clay and large boulders.

The average daily progress rate achieved by the TBMs in the difficult geological conditions was 15m-20m, said NFM.

In total, each tunnel will be 3.63km long and the twin bore crossing of the Yangtze is part of a new main artery route that will run north-south across the city, which is divided by the Yangtze and Han rivers (*T&TI*, March 2007, p7). The road will be a double carriageway with two lanes each in the tunnels.

Above: **Celebrations in Wuhan, China, when the first of twin NFM slurry TBMs holed through after driving below the Yangtze river**

Immersed tube HK-Shenzhen link

An immersed tube road tunnel is to be built below a major shipping channel for a transport link between Hong Kong's international airport and a key highway to southern China.

Highways department officials in Hong Kong kicked off the project last month. They invited consultants to express interest in carrying out an initial investigation and preliminary design for the transport scheme.

Companies interested in bidding for the studies had until 31 January to apply for work covering the Chek Lap Kok airport to Tuen Mun (in the north-west New Territories) link. The new link will includes the 4km long immersed tube as part of the 9km long highway.

Firms also have until early this month to express interest for a separate assignment on the adjacent 8.5km Tuen Mun western bypass, which is to include 5.8km of tunnels.

Local legislators approved US$11.3M to finance the two consultancy packages. Early studies for the scheme were done by Australian firm Meinhardt.

Highways officials are aiming for the consultancy contracts to commence in May. They want the studies to refine the cost, route alignment and size of the road scheme, including the tunnels, which are likely to be wide enough for a dual two-lane highway.

Preliminary and detailed design is likely to take until May 2010 to complete and then construction is not expected to begin until 2011 for completion of the project in 2016.

With an estimated cost of approximately US$2.6bn, the link will pass under the Urmston Road shipping channel and the bypass will provide fast access to the existing Kong Sham highway and on to the western side of Shenzhen, the fast growing border city.

Seed vault set to store

Construction of the tunnelled vault in the Norwegian Arctic to store seed samples from around the world has been completed. The stocked caverns of the food and biodiversity security facility were set to be officially opened late February.

Drill and blast excavation of the "Doomsday Vault" complex near Longyearbyen on Spitsbergen, the main island in the Svalbard archipelago, started in April 2007. A 120m long main access tunnel was driven from which an access gallery was opened up left and right, and then three storage caverns were excavated.

The bored distance from the portal to the rear of the caverns is almost 146m. Each cavern is 9.5m-10m wide by 6m high and approximately 27m long. Geology at the site comprises only sandstone. The air inside the complex was chilled over two months to lower the rock temperature within a 10m zone from -5° C to -18° C.

The subterranean seed store will be marked by a highly visible reinforced concrete access portal that houses artwork, including lights, that change with the length of Arctic day. For security, a series of gates are fitted to the portal structure.

The project was directed by Statsbygg, the Norwegian government's Directorate of Public Construction and Property. The government invested US$9M to build the scheme, which will be run by the Global Crop Diversity Trust. The vault was built approximately 130m above current sea level to outlast any changes brought by climate change problems.

An artist's impression of the Norwegian Arctic seed store

Tiger drives line up

Excavation of two tunnels under a tiger reserve in Andhra Pradesh, India, for a major irrigation scheme are to be undertaken by separate contractors using a Herrenknecht TBM currently being assembled onsite and a larger diameter Robbins machine that is not due to start its drive for a year.

The bores are strategic parts of the Pula Subbaiah Veligonda scheme, which will transfer water from Srisailam reservoir to an irrigation canal network. The scheme is being developed by the state government and some of the flow will be used for drinking water in Prakasam District to overcome problems of contaminated groundwater supplies.

Onsite assembly work for the 7.9m diameter Herrenknecht double shield TBM (S-370) is underway and that drive is due to start within months. The shield has cutterhead power and torque of 2,800kW and 5,844kNm, respectively, and total thrust of 56,000kN.

Geology along the alignment of the 18km long drive comprises quartzite, shale and phyllite with UCS of 90MPa-225MPa. The hard rock, segmentally lined tunnel will not include any intermediate adits or shafts as it is bored below the Nagarjunasagar nature reserve. Few faults or inflows are expected to be encountered.

Herrenknecht subsidiaries are also working on the contract, called Pula Subbaiah Veligonda Tunnel No 1. The manufacturer of the honeycomb segments is Herrenknecht Formwork Technology, and TBM operation and maintenance will be by local unit Underground Technology Services India.

The state government hired a joint venture of Iran's Sabir, Indian firms SEW Constructions and Prasad to be the main contractor. The consortium subcontracted the tunnelling package to NSC Consortium, which is a JV of local firms Nuziveedu Seeds, Swathi Constructions and Coastal Projects.

TBM to drive one of the two Veligonda water transfer tunnels, in India

Coastal Projects is also part of the JV with Indian contractor Hindustan Construction Co that is to build the parallel, No 2 tunnel with a 10m diameter Robbins double shield. The tunnel will have a 300mm thick segmental (6+1) lining to give a finished diameter of 9.2m.

In addition to the shield, Robbins is supplying a full package of the back-up system, spare parts, back-loading 20" cutters, conveyors and key staff. A 19.2km long continuous conveyor with three booster drives is to be used for spoil removal.

The second, larger tunnel is to be built approximately 60m from the No 1 drive, and launch of the TBM is scheduled for February 2009. The JV customer was awarded the contract in October 2007, and Robbins said the major components should reach site for assembly by October this year.

The TBM will be initially assembled in a pit at the jobsite rather than in one of the company's manufacturing facilities, and use components made in the US, China and India. The jobsite assembly will save money and time for the contractor, said Robbins' president, Lok Home. Once assembled, the TBM will be walked to a 25m long launch chamber.

The Sabir-SEW-Prasad JV is also building a 100m long "Approach Channel", in tunnel, between the reservoir and the entrance to the conveyance tunnels. The three-year contract began in late 2005.

MTR studies border rail tunnel

MTR Corporation has launched plans for a study of the Hong Kong side of the cross-border express rail link with China, the section that will involve the most tunnels.

The company has invited submissions of interest from multi-disciplinary teams for a contract to perform the detailed design of 26km of tunnel, which represents most of the Hong Kong section.

The assignment involves finalising the route alignment, cost and construction details of twin tunnels and associated structures, such as ventilation shafts and construction access points. The rail link must also connect with MTR's west Kowloon terminus and the Kowloon Southern Link tunnels.

Firms were also invited to express interest in a separate consultancy covering the preliminary design of the west Kowloon terminus. The Kowloon Southern Link is already under construction (*T&TI*, November 2007, p10). The express rail link will run from the west Kowloon terminus to the border with Shenzhen.

MTR took over responsibility for the link following its merger with the Kowloon-Canton Railway Corporation (KCRC) in December 2007.

Budget information on the rail link was not confirmed. However, the link is part of the Hong Kong to Guangzhou via Shenzhen transport projects in the package of 10 infrastructure schemes worth US$32bn announced in October 2007.

Separately, MTR has secured US$51M in funding to prepare for the US$1.14bn West Island Line extension. The company is also going ahead with the US$900M eastern section of the South Island line, to be built mostly underground. Consultants are bidding for each project.

Dig starts at Devil's Punch Bowl

Groundbreaking took place at that start of February at the Devil's Punch Bowl off the A3 highway, in southern England, for excavation of the twin bore Hindhead Tunnels.

The 1.83km long bores are being constructed by the sprayed concrete lining (SCL) method and the scheme was developed under an early contractor involvement initiative of the Highways Agency with Balfour Beatty. The tunnel is to open by 2011 and the new road completed by March 2012.

Geology along the route comprises sedimentary deposits, principally fractured sandstone of varying strengths (2MPa-5MPa) with occasional thin beds of clayey/silty fine sand, although some stretches of the excavation will meet more sand material. The tunnel elevation is almost all above the historically observed water table (*T&TI*, June 2007, p23).

The horseshoe-shaped bores will hold two lane carriageways and safety cross passages are to be built at 100m nominal centres. The excavated diameter will be 11.6m to give a face area of 96m^2, and the finished width 10.6m.

SCL was chosen over other excavation methods, such as TBM, following an analysis that determined it to be the most economic option – the shield alternative requiring a 2.5km tunnel before it could be viable for two drives.

The start of excavation follows a year after work on the US$720M road realignment project commenced to dual the last, 6.5km long section of single carriageway. By realigning the road the project will not only remove a traffic bottleneck but help to protect the Devil's Punch Bowl, which is a designated Site of Special Scientific Interest (SSSI).

A road improvement project for Hindhead had been on the drawing board for 25 years. Over the period the balance in benefits sought has tilted more to environmental protection in comparison to economic benefits.

Rail-to-water tunnel conversion

A network of up to 10 disused rail tunnels under the centre of Sydney could be converted for stormwater storage under plans being considered by the New South Wales Government.

Under the scheme the tunnels would store stormwater for secondary, non-potable uses such as flushing water in toilets or washing in an effort to reduce the requirement for fresh water in the face of severe droughts. The scheme would supply government and public buildings in the central business district.

If the plan is approved. the state government aims to turn the disused station at St James into a major water storage facility, according to Acting Minister for Climate Change Nathan Rees. The former rail station and its associated running tunnels were built in 1922 as part of a line to Daceyville that was subsequently abandoned.

State Transport Minister John Watkins recently asked state rail network manager RailCorp to carry out a feasibility study into the tunnel conversion plan. 'The government will consider any means of providing additional water to government buildings in the central business district especially during the drought,' he said.

RailCorp declined to pinpoint the exact location of the tunnels that could be converted into storage facilities but they are thought to include links at Redfern, Central Station, North Sydney and St James.

Separately, the Liberal Party in Canberra has also proposed the construction of a US$62M tunnel to extract groundwater to help in the growing water crisis in the Australian Capital Territory. The party envisages construction of a 10km long tunnel up to 4m in diameter, the portal being close to the Gudgenby river at Glendale Crossing. The tunnel would be gravity-fed.

The hydrologist for the party's Delegate River Group, Jim Johnson, said further engineering and scientific studies would be needed before the scheme could proceed although these could be completed for less than US$900,000.

Gotthard greenlights Erstfeld section

Excavation of the delayed Erstfeld section of the Gotthard Base Tunnel is underway and the client AlpTransit Gotthard has also been able to reach an out-of-court deal to enable work to start on fit-out of the completed sections of the 57km long twin-bore rail link.

By the end of last month the refurbished 9.58m diameter Herrenknecht TBM ("Gabi I", which was S-229 and has been renamed S-421) had advanced 368.5m. Full operation is due for April. Gabi I is to drive the 7.2km east tube to the Amsteg section of the scheme and excavation is scheduled to be completed in December 2009.

The sister machine, "Gabi II" (which was S-230 and will be S-422) was being assembled for relaunch shortly to bore the parallel west tube. It is to drive at full power from May and breakthrough is expected in February 2010.

Gabi I and II completed their previous drives on the Amsteg section of the project in June and October last year, as S-229 and S-230, respectively. The AGN JV (comprising Murer-Strabag, and Strabag) built the Amsteg section and are building the Erstfeld section with the same machines.

The project will be the world's longest tunnel on its opening, which is scheduled for 2017, and it is the central scheme for Europe's expanding rail network. However, the programme had had more risk against achieving the timetable when an appeal was lodged against the award of the US$1.5bn rail infrastructure contract in May 2007.

The client and the Swiss Railway Infrastructure Consortium Gotthard (SBK) reached an out-of-court agreement for the appeal to be withdrawn, which AlpTransit said would help to avoid potentially years of delay in legal battles. AlpTransit said it would pay the JV a one-time sum of US$907,000 to cover tender costs.

Members of the SBK JV include Implenia Bau, Sersa Group Management, Rhomberg Bahntechnik, Siemens Schweiz, Murer-Strabag and Walo Bertschinger.

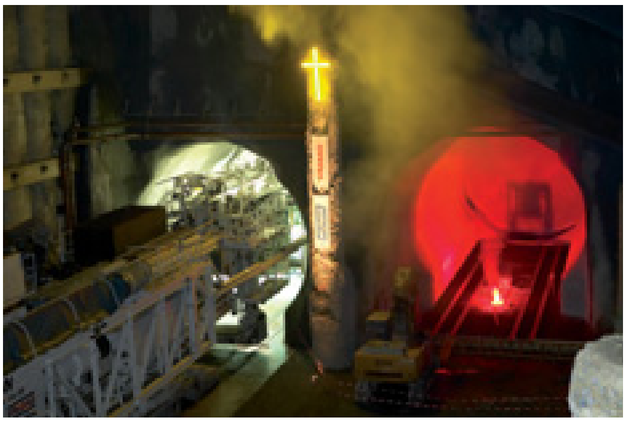
The rail contract was awarded last year to the Transtec Gotthard Consortium, which includes: Atel Installationstechnik, Alcatel-Lucent Schweiz, TRSS Thales Rail Signalling Solutions, Alpine-Bau, and Balfour Beatty Rail. The client has been informed that SBK JV has entered into a deal with the Transtec venture but details were not disclosed.

The rail infrastructure contract - to be signed shortly - covers fit-out for twin single track tunnels, each 57km long in the tunnels, as well as approximately 11km for each line to link up to the existing rail network. Installation work is to start in mid-2009.

Almost 70% of the total excavated on the Gotthard rail scheme has been completed and

Grippers bracing walls at start of first Erstfeld drive at Gotthard

preparatory work is underway for the associated 5.4km twin-bore Ceneri Base Tunnel, for which the TBM starter tube has been completed. The start-up ceremony for the machine was planned at Sigirino for mid-February. A Robbins main beam TBM that has been refurbished and increased in diameter will drive the 2.4km adit from Sigirino later this year. Last month drill and blast excavation for the installations cavern commenced.



TBM launch on the Erstfeld section of the Gotthard Base Tunnel

'Eliza Jane' shows face at Glendoe

In the hills above Loch Ness in the Scottish Highlands, the 5m Herrenknecht TBM 'Eliza Jane' holed through last month to complete the headrace bore after more than a year of excavation.

The hydropower project is being constructed under a design and build contract by the Hochtief-Glendoe JV. Hard rock tunnelling is rare in the UK these days, most large diameter work being metros and sewers in the soft ground of most urban environments.

Construction on the project also includes a significant amount of drill and blast work for access and water transfer tunnels and the powerhouse cavern (*T&TI*, April 2007, p21). The contractor's engineer is Pöyry. The client is Scottish & Southern Energy (SSE).

TBM completes headrace drive at Glendoe scheme, Scotland

Robbins TBM to burrow below mine

Improvement in drainage in a copper mine in Papua New Guinea is to be achieved by a refurbished Robbins TBM. The machine is being delivered soon, on a fast-track schedule, to start burrowing shortly to complete a series of tunnels below the operations within a year.

The 5.6m diameter machine is to start the first of three drives within the first quarter of this year and Robbins target for delivery to site is only six months after the order was placed by the Ok Tedi Mine. The owner might use the dewatering tunnels to extend the life of the current operations and then it may prospect in them for deposits of gold or copper.

Three tunnels of 4.2km, 1.2km and 900m lengths, respectively, are to be excavated by the refurbished TBM. Geology below the main operational zone of the mine comprises siltstone, intrusive porphyry and limestone that may have fault or karstic voids. While the average rock strength is estimated to be 100MPa it is expected the maximum will be 285MPa.

Under the contract, Robbins is supplying the main beam TBM, 19" cutters, spares and the back-up system as well as undertake onsite assembly and commissioning. The TBM will probe up to 100m ahead of the face in the dewatering tunnel drives to investigate groundwater conditions, Robbins said. Roof support will use 2.4m rockbolts.

The machine, which previously worked on the Little Calumet section of the Tunnel and Reservoir Plan (TARP) in Chicago, will use an invert thrust system in any fault zone encountered, Robbins said. In addition, to reduce the gripper force on the rock walls the machine will push off the concrete invert in the tunnel.

Above: The copper mine site in Papua New Guinea where a Robbins TBM will bore over 6km of drainage tunnels

Lovat in Nizhny, due out at Vancouver

Lovat has signed a deal to supply Russian contractor Mosmetrostroy with the refurbished EPBM from the London DLR for the Nizhny metro, and is due to see another EPBM driven by the Seli-SNC Lavalin JV hole through on the second tube of the Canada Line rapid transit in Vancouver.

The 6m diameter EPBM is to drive parallel 1.4km tunnels for Nizhny metro, in Nizhny Novgorod, through mostly sedimentary strata comprising deposits of clay, loam and sand as well as rocks such as marl, sandstone, siltstone and dolomite. Cover will vary 10m-42m over the crown and groundwater levels 9m-35m above the tunnel invert.

The machine recently completed the twin tube drive in London for the Woolwich extension to the Docklands Light Railway. Refurbishment of the RME238SE Series 21801 machine, including fitting with a new mixed face cutting head, is to take place at the jobsite, Lovat said. It is expected the drive will start shortly.

The manufacturer is also supplying an EPBM to the contractor for its work on access drives for escalator tunnels in Moscow's metro. The 11m diameter machine has been designed to be able to bore at a steep incline, is capable of a 100m diameter vertical radius turn and can be dismantled within the tube and extracted (*T&TI*, January, p7).

Breakthrough is expected this month on the final bore on the twin tube tunnels being built for the Canada Line in downtown Vancouver by Seli-SNC Lavalin JV. The 6.1m diameter mixed face EPBM holed through on the first tube in April last year after about nine months of excavation.

A two-part annular grouting system is being employed on the drives with the RME238SE Series 22400 machine. The second drive on the parallel approximately 2.5km long tunnel started mid-2007 and was expected to take about 10 months. By mid-December last year the EPBM had bored 1.9km.

Averaging just 18m per day of lined tunnel, the best daily progress was recorded as 29.4m and the best six-day week was 147m. Best progress in a month was 463m, achieved last August. Geology along the route comprises sandstone, granite and glacial till with a high groundwater level. On the first bore the average advance through the variable ground was 10m per day.

Korea-China tunnel aired

Concepts for a major tunnel scheme that would run between the peninsulas of Korea and China, at Weihai, have been aired in the midst of the recent elections in South Korea.

The concept plans are being prepared by the provincial government of Gyeonggi, South Korea, which holds about a fifth of the country's population.

Gyeonggi is reported to have submitted its suggestions for the tunnel to the transition group set up by South Korea's newly elected president, Lee Myung-bak, who takes office in late February.

Three different routes are understood to have been included in the concept proposal, each terminating at the port of Weihai in China's Shandong province, to the east of South Korea. Initial estimates suggest that a subsea link from the city of Pyeongtaek, in Gyeonggi province, to Weihai would be the most economic of the options presented.

Such a tunnel connection would help traffic avoid the circuitous route around the coast, including avoiding any need for links via isolationist North Korea, which is at the neck of the Korean peninsula closest to China. However, no details of how the major scheme would be funded or built were released. Such as scheme is expected to take some decades to complete.

Strabag buys Adanti

Strabag has taken a strategic step into the Italian tunnelling sector through the acquisition of the contractor Adanti.

The Bolonga-based contractor was bought from SECI, which is the holding company of Adanti's Italian parent Maccaferri. Details of the price and terms of the 100% acquisition were not disclosed.

Adanti is currently working on a road contract valued at approximately US$100M that involves tunnelling work in Carrara, north of Pisa, Italy. The company is working on Lot 2, a 4.56km long stretch of new road, tunnel and viaduct.

A total of just over 3.6km of the route will be in tunnel, the main tunnelling on Lot 2 being a 2.4km long section. The other key tunnels are 972m and 211m long, respectively. The contract for client Progetto Carrara is due to be completed early 2011. Including Lots 1 and 2, the total length is 5.6km just over 4.6km of which is in tunnel.

Strabag said it plans to position Adanti as a leading contractor in the Italian market in the medium term and noted the firm's strengths in tunnelling.

Adanti had revenues of US$234M in 2007 and employs almost 400 staff and workers.

Detroit seeks bids for Upper Rouge CSO

With an increasingly busy tunnel workload, the City of Detroit Water and Sewerage Dept (DWSD) is calling for contractors to bid to construct the 5.75km long south tunnel Upper Rouge combined sewer outfall by 03 April.

The tunnel is to be excavated 46m below the surface and have a finished diameter of almost 9.25m. Proposals for the initial and final tunnel linings will be accepted in the bids for Contract No PC-764.

In addition to the main tunnel, the contract calls for construction of a 24.6m wide by 61.5m deep access shaft from which the TBM will be launched, and six connecting adits/deaeration chambers of 2.15m-9.85m i.d. varying in length from 24.5m-443m.

The bid bind is 5% of the tender sum. Offers will be open for acceptance by DWSD for 120 days from 3 April, when the bids will be opened.

Elsewhere in the city, DWSD plans to try again to build Outfall No 2 and has called for contractors to prequalify. The initial attempt was abandoned due to severe flooding, which led to the loss of the works and contract termination. DWSD plans to build the new, 1.9km long, 7.4m excavated diameter sewer tunnel above the old drive, which is to be backfilled (*T&TI*, January, p12).

Crossrail moves to the Lords

The Bill for London's Crossrail project was to move to the select committee hearings in the House of Lords in mid-February.

In mid-December, the Bill completed its third, and final, reading stage in the House of Commons and was introduced the next day to the House of Lords, which triggered a new petitioning period to 30 January.

Developer Cross London Rail Links' chairman, Douglas Oakervee, said the move of the Bill to the Lords was a major step for the project. Following the Commons' readings, he added: "The debate confirmed the prevailing sense that, across the political parties, Parliament is keen to see the Bill progress speedily".

Assuming the Bill is cleared, receiving Royal Assent, before mid-year then tunnel excavation on the project is scheduled run from mid-2011. Trial runs of first trains is due to take place in 2017 (*T&TI*, December 2007, p28).

Recent developments with the project also saw the government formally protect, or safeguard, additional corridors to the west of London for a possible extension of the rail link. A possible extension east is also being looked at.

Robbins is working with U Mole to sell its small boring units to key European markets

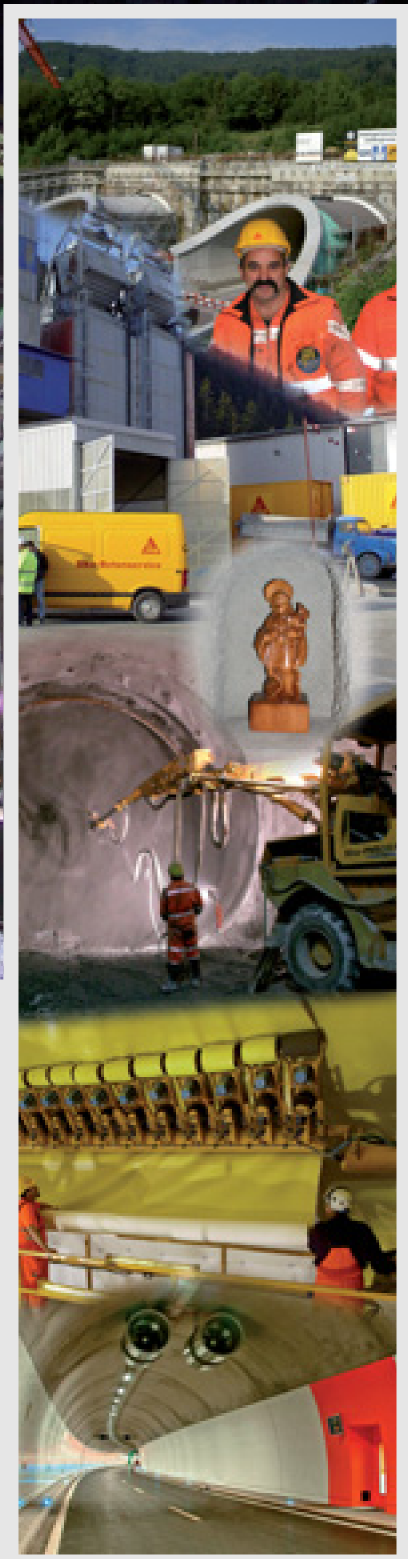
U Mole to rep for Robbins in small bore machines in Europe

US TBM manufacturer Robbins has appointed England-based U Mole as sole representative to market its small boring unit machines, plus provision of spares and consumables, to a number of European territories.

The key territories where U Mole will represent the unit are the firm's hometurf in the UK as well as Belgium, Denmark, Eire, France, Netherlands, Norway and Sweden.

In a statement, the UK firm's managing director, Russell Fairhurst, said: 'This is a significant agreement for us and takes the company into a whole new product area.'

Robbins' small bore unit has four product areas, covering motorised, rockhead and auger boring machines.



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Brenner's gearing up

A US$2.9bn 40km section of new twin-track railway, built almost entirely underground, is the scope of a capacity upgrade through the Lower Inn Valley, in Austria. Technical journalist, Shani Wallis, travelled to Innsbruck to appreciate the undertaking and find out how the line fits into the TransEuropean Brenner Baseline project

Above: **Fig 1 - The Lower Inn Valley update is part of the Munich to Verona project**

Europe's continuing commitment to improving rail services places the continuous connection from Berlin to Palermo as the number one priority. Central to this is the 56km long Brenner Baseline Tunnel through the Italian-Austrian Alps. That is the epic challenge, yet equally demanding is construction of upgrades along the 2400km corridor.

Long sections of the route in Italy and Germany are complete (figure 1), with passenger and freight trains flying through substantial sections of hard-won tunnels. Today, the focus is Austria where attention is addressing capacity concerns through the Lower Inn Valley, between the border with Germany and Innsbruck, Austria's gateway to the Brenner Baseline Tunnel.

Being at the heart of Europe, the Inn Valley section is not only critical to the north-south Berlin-Palermo axis, but also to east-west traffic. Currently the line carries 300 to 340 local and long-distance passenger and freight trains per day, with some 12M tonne of rail freight being carried on the existing 78km, hour-long trip, over the Brenner Pass per year. This load is set to increase steadily year-on-year and climb substantially once the 15-20 minute trip through the 56km long Brenner Base Tunnel opens. Ahead of that, the first upgrade section of the Lower Inn Valley route, between Baumkirchen near Innsbruck and Kundl just south-west of the main rail junction at Wörgl, will support an increased 400 train trips per day when opened in 2012.

Valley feat

Building new rail infrastructure through Europe is no easy matter. Social and environmental constraints, alignment options and budgets are pressured by location, logistical and constructability concerns.

Flanked by the towering Alps, the narrow Inn Valley leaves little space on the surface for new infrastructure. As well as the valley's namesake river, the 40km long Phase 1 project area accommodates 31 separate communities of private and commercial rural and urban property, existing surface rail routes and the regional section of the E60 TransEuropean highway. With precious little room on surface, nearly all of the new rail alignment is underground, cutting into the mountains at two locations and threading its way once under the river, seven times under the motorway, and ten times under existing rail lines.

Austria is not readily associated with soft-ground tunnelling, but some 48% of the route runs beneath the high groundwater table of the valley, often within metres of the river. This has demanded specialist methods including two slurry TBM drives, compressed air and jet-piled support of open-face tunnel excavations, and subaqueous open-cut works. These are in addition to two long drill & blast and top-heading, bench and invert tunnels through the mountains at Brixlegg and Vomp and sections of cut & cover with minimum surface work in between.

Planning and design of the new line began in 1996 and authorisation of funding in 2002 gave the green light for construction to start in August 2003. As part of the EU's current focus on the Munich-Verona section of the overall Berlin-Palermo project, planning and design of the upgrade was funded 50/50 by Austria and the EU and its US$2.9bn construction cost is funded 95% by Austria and 5% by the EU.

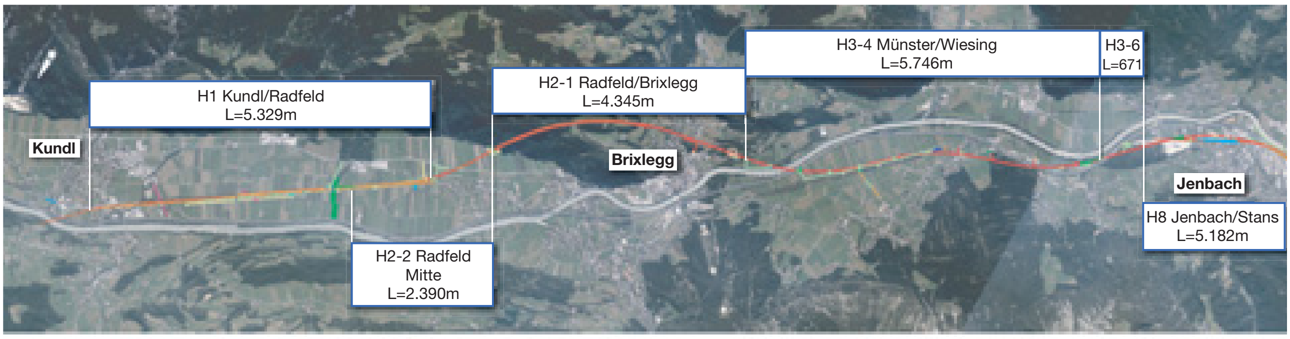
Upgrade of existing lines for the project in Austria is managed by BEG, Brenner Eisenbahn GmbH, a company of the Austrian railway company ÖBB. Brenner Basistunnel SE (BTT), a 50/50 Austrian/Italian JV European stock company, is managing realisation of the estimated US$8.75bn baseline tunnel. RFI, the national railway authority of Italy, is managing the Southern Approach works from Verona to the base tunnel, and DB in Germany is managing the Northern Approach needs from Munich to the Austrian border.

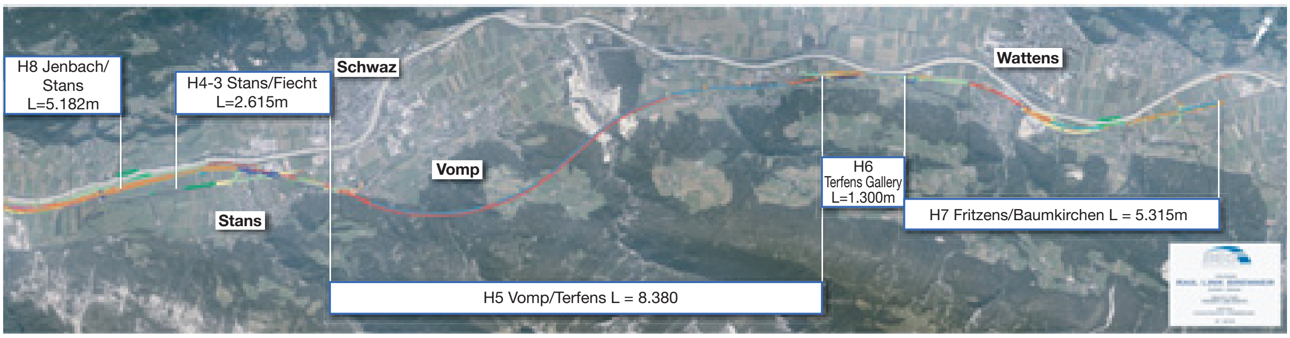
In Austria, the current 40km Lower Inn Valley upgrade is a complex affair comprising more than 1000 different procurement contracts. More than 400 of these were running when *T&TI* met BEG general manager Dipl.-Ing. Johann Herdina in October 2007. At the same time, BEG is progressing planning and design of the next Inn Valley rail upgrade for the 22km section from Kundl to the German border.

Of the 10 principal construction contracts on the current project, two were complete by

Table 1: Details of the 10 principal construction lots

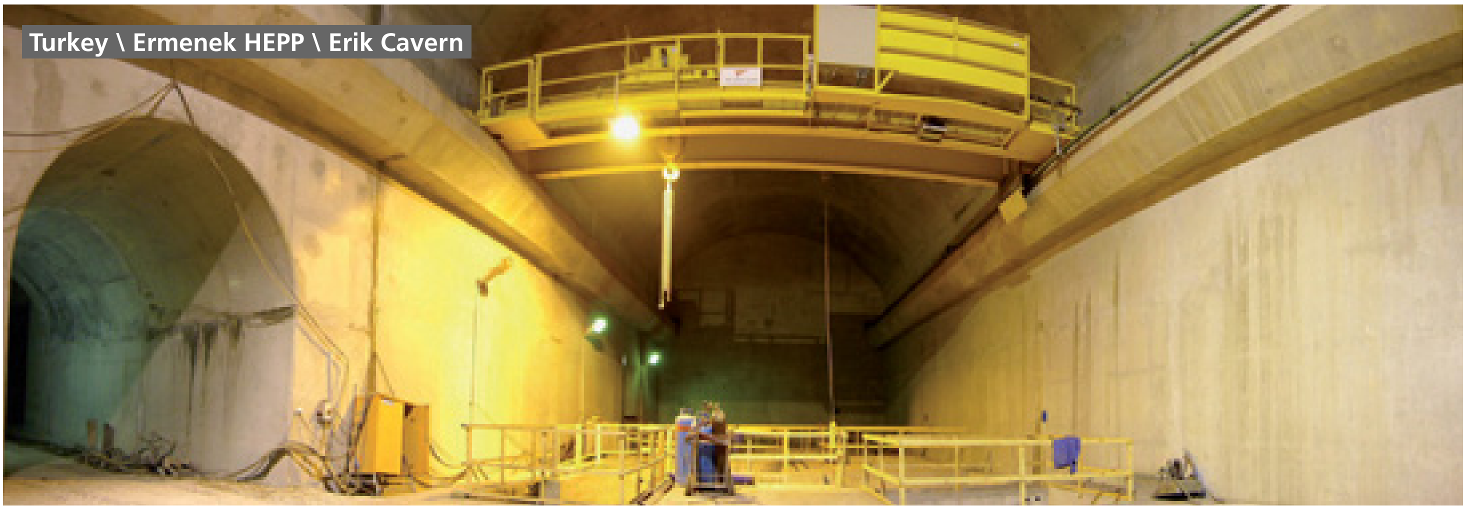
Contract	Principal designers	Contractor JV	Contract price	Start	End
Lot H1 Kundl-Radfeld **Length - 5,329m** Upgrade of existing and 900m of new surface track	Spirk & Partner, Pauser ZT, Obermeyer, ILF, GTH-Geotechnik Hammer, ISF	To let in summer 2008	-	July 2008	July 2010
Lot H2-2 Radfeld Mitte **Length - 2,390m** 790m of open-cut and 1,600m of conventional mined tunnelling	Geoconsult/Baumann+Obholzer Spirk & Partner/Obermeyer D2 Consult/SEIB	To let in Feb 2008	-	March 2008	April 2011
Lot H2-1 Radfeld - Brixlegg **Length - 4,345m** Topheading, bench, invert Shotcrete primary lining and in-situ concrete final lining	Müller Hereth ILV/Vössing	Porr/Bilfinger Berger Hinteregger/Östu Stettin	US$96.4M	July 2004	Dec 2006
Lot H3-4 Münster - Weising **Length - 5,746m** Slurry shield tunnel - 13m diameter 11 emergency escape shafts Segmentally lined	Spiekermann Obermeyer ibk/Metz & Partner D2 Consult/Oksakowski Maidl+Maidl	Porr/Max Bögl JV	US$225M	April 2006	Dec 2010
Lot H3-6 Tiergarten Tunnel **Length - 671m**	Geoconsult, Obermeyer ibk/Metz & Partner D2 Consult/Oksakowski, IPH	Beton-und Monierbau/ Alpine Mayreder/ Jäger JV	US$20.4M	May 2007	Aug 2008
Lot H8 Jenbach/Stans **Length - 5,182m** Slurry shield tunnel – 13m diameter	Obermeyer	Strabag/Hochtief/Züblin JV	US$219M	July 2006	Aug 2010
Lot H4-3 Stans/Fiecht **Length - 2,615m** 1060m of open cut 750m of beneath highway viaduct 805m of cut + cover, a 634m spur tunnel	GeoConsult/ILF	Alpine Meyreder/ Grund-Pfahl-und Sonderbau JV	US$152M	Aug 2005	Feb 2010
Lot H5 Vomp-Terfens **Length - 8,380m** Conventional tunnelling	GeoConsult Geodata/AVD ste.p, Oksakowski/D2 Consult	Strabag/Züblin/Hochtief JV	US$273M	Aug 2003	Dec 2008
Lot H6 Terfens Gallery **Length - 1,300m** Avalanche protection gallery	Baumann+Obholzer/Geoconsult ILF, Geodata/AVD, ste.p	Strabag	US$27.7M	Oct 2003	May 2007
Lot H7 Fritzens/Baumkirchen **Length - 5,315m** 3,940m of topheading, bench, invert tunnel using horizontal pre-support, and face nailing between 624m of open-cut and 750m of surface work	GeoConsult ste.p Obermeyer/GEC/Spirk & Partners IBPA IPH HBPM	Strabag/Züblin/Hochtief JV	US$203M	Feb 2005	Dec 2009






Austria \ BEG \ Lot H 4-3 (Stans)


Bulgaria \ Tsankov Kamak HPP \ Plunge Pool


Turkey \ Ermenek HEPP \ Erik Cavern


Austria \ Vienna \ Lainzer Tunnel (LT 31)

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Above: Double-track top heading, bench and invert tunnelling

Right: Assembly of the Herrenknecht Mixshield for the Jenbach Tunnel ahead of a cell of subaqueous open-cut work

October 2007, two were to be awarded in 2008 and six were in progress. These six represent some 28km of the 40km alignment, which is 70% of the total construction effort in progress simultaneously. All tunnelling and sub-surface excavation on the alignment is programmed to be complete by the end of 2008. This is also the year of highest capital expenditure amounting to over US$380M of the total US$2.9bn project and following consumption of about US$313.7M in both 2007 and 2006. M&E installation is scheduled to start this year too, with a programmed opening in December 2012.

Single-tube, double-track

All underground sections on the alignment are designed as single-tube, double-track structures. The drill & blast and open-face excavations have a 134m^2 cross section for a finished 8m high x 11.4m wide structure. The largest open-face is a three-track overtaking section in the H5 Vomp-Terfens drill & blast tunnel that has a 17.4m wide x 12.5m high (202m^2) excavated cross section. These open-face tunnels have a primary support of shotcrete with rockbolts, dowels, lattice girders and wire mesh, with a drained PVC membrane waterproofing system behind a rebar-reinforced, cast in-situ concrete final lining of 300-700mm. Shotcrete in the main excavations is wet mix with dry mix for smaller applications such as small shafts and slope stabilisation work.

The two slurry shield drives are 13m o.d. and are lined with 2m wide x 500mm thick, bolted and gasketed rings of steel rebar reinforced segments for a finished double track i.d. of 11.23m.

The rail line being built is a product of design principles that prevailed in the 1980s and 1990s. These have since come under rigorous analysis and if planned today, designs might be quite different. BEG general manager Johann Herdina explained.

"The concept of two tracks in one large tunnel has required a substantial amount of extra excavation on this project," says Herdina. "Not only for the large double-track cross-sections in these particular geological conditions, but more especially for the necessary fire-life-safety and evacuation facilities. The long Vomp-Terfens drill & blast tunnel for example has a 5.8km x 25m^2 escape/service tunnel running parallel to the main tunnel with linking adits of up to 20m long at regular 500m intervals.

On the 5.8km long Münster-Wiesing TBM tunnel there are 11 evacuation shafts at 500m intervals. These were placed close to the tunnel alignment but in one instance the available surface space for shaft construction has required an adit of 132m. These are expensive project elements. The average depth of the eleven 8m i.d. shafts is 30m and the average length of the connecting adits is 43m. The seven evacuation shafts on the 3.6km long Jenbach TBM tunnel are on average 25m deep and 50m long."

Planning today, suggested Herdina, might be based more cost effectively on twin single-track tunnels with regular linking cross passages, which would allow the parallel tube to double as the emergency escape route, thus eliminating the need for separate emergency tunnels and evacuation shafts. "This would save substantial cost," he says.

There was discussion also about the cost of building and operating high-speed railway lines underground. "If new mixed-use freight and passenger railways are to be built underground, the facilities must have the most up-to-date standards in fire-life-safety equipment and systems," says Herdina.

These are becoming expensive long-term operating costs that do not apply to surface sections of the network. Other factors influence the final decision between surface or subsurface alignment, including important environmental concerns and land acquisition costs, but a suggested way around the dilemma, says Herdina, might be to build the new underground lines strictly for freight trains and reserve the existing largely surface alignments for passenger services.

The long underground freight-only tunnels would not require the same degree of public fire-life-safety facilities and the cost-effective advantages of building large double-track tunnels could be retained.

On long tunnels where the timesaving factor is needed for high-speed passenger trains, the option would be overruled, but these and planning, design, and operating issues are being discussed as part of future high-speed rail projects says Herdina.

"We are currently studying all these issues with regard to the next 22km long phase of the Lower Inn Valley upgrade, where tunnelling and underground construction is likely to be required for logistical and environmental reasons, but where more than 80% of the current 40km length of Phase 1 is underground, we seek to have less than 50% of the 22km Phase II in tunnel."

In the meantime, work as designed progresses on the current project.

By early January 2008, after four-and-a-half years, civil work on the 40km of new twin-track railway was about 50% complete. "We have had our testing challenges," says Herdina, "but progress at present is promising and on programme to complete excavation by end 2008/early 2009 and to meet the December 2012 opening date."

Construction progress

Of the six construction lots in progress in January 2008, excavation of the 8.38km long H5 Vomp-Terfens Tunnel and its 5.8km parallel service/evacuation tunnel was complete and installation of the final waterproofing system and in-situ lining was 90% complete. Excavation of the 671m H3-6 Tiergarten Tunnel was advancing towards completion in April when a single front of waterproofing and concrete lining will complete the drive by the end of 2008.

Above: Cells of sub-aqueous open cut construction below the high groundwater table on the H7 Fritzens-Baumkirchen

Left: Transition from a cut & cover section to mined-tunnel excavation using pipe-umbrella pre-support, face nailing and compressed air to control groundwater

On the two TBM tunnels, the first of the two Herrenknecht slurry Mixshield systems was 1.5km into its 5.8km long Münster-Weising drive and the second, for the H8 Jenbach lot, had just launched. When *T&TI* was on site in October, the refurbished machine, first used on the SMART tunnel in Kuala Lumpur, was in assembly and had cut its first metres in November at the start of its single 3.6km drive towards the H3-6 Tiergarten Tunnel lot.

Between these open-faced and TBM drives are several sections of open-cut work. Methods of constructing temporary works and non-permanent measures was up to each contractor to select and all on the relevant lots chose the open-cut subaqueous method of excavation without lowering or otherwise controlling the groundwater. After installing sheet piling to create closed cells of 15.5m wide by up to 150m long, the core is excavated in wet conditions up to 15m deep. The concrete slab is tremmied in and anchored down against the groundwater uplift before the now watertight sheet-piled cells are pumped dry.

There are also lengths of open-faced excavation through waterbearing conditions that use compressed air to control groundwater. This is used in conjunction with pipe-umbrella pre-support across the vaults of the 60m^2 top-headings and a programme of vertical pre-excavation jet grouting to pre-support the sidewalls of the bench and invert excavations. Compressed air conditions on these three contracts, and for a total 4.1km of tunnelling, have ranged from 0.34 to 1.5 bar. Compressed air of up 3 bar is also used for man-entry in the excavation chambers of the slurry TBM drives.

One of the most demanding sections is the 2.6km long Lot H4-3 section through the village of Stans. Here the subsurface alignment runs almost directly in line and beneath the highway and surface rail tracks and incorporates a spur tunnel to link south bound traffic to the existing west bound surface rail line. Construction of this section has required four different methods and a total 21 phases of motorway diversion.

The first 525m and last 805m lengths are open-cut above the groundwater table. Another 535m below the water table is constructed in cells of subaqueous open-cut work but it is the last 750m section beneath the highway, the railway, and the water table, that called for special attention.

That special attention was provided by mined tunnel excavation under the control of compressed air and within the security of a ring of vertical pre-excavation jet-piling pre-support (figure 2). "This section caused us the most technical challenge," says Herdina. "The highway and railway above added to the complexity of the situation and a bored tunnel was the best and yet the most complex solution."

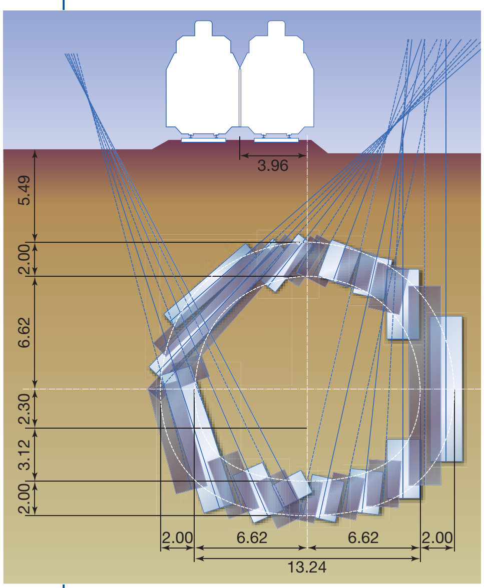
To begin, a test section of comprehensive vertical jet-piling confirmed that the concept could be used and allow for safe mining on a top heading, bench and invert. Work started with mobilisation of a high-capacity grouting operation to install the vertical jet-piling in 20m x 12m long blocks. Exact drill patterns and packer positions achieved accurate installation of the 2m thick ring of pre-support grouting. Angled drilling from either side of the surface railway and underneath a section of elevated highway, that could not be diverted, achieved the jet piling operation.

"The ring of jet-grouting performed exceptionally well," reported Herdina. So well in fact the compressed-air work environment needed positive venting to compensate for very low air losses and keep the area fresh. "Yes, it was an expensive solution, but it was highly effective."

Another difficult section to complete was the last part of the 8.38km Vomp-Terfens Tunnel where drill & blast had progressed from the western portal in Terfens and in both directions from an intermediate adit. As the heading approached the breakthrough portal it suffered a collapse at the interface between the hard rock of the mountain and the zone of unstable rockfall material at its base. Recovering from the collapse and completing the tunnel to breakthrough proved exasperatingly slow. It took 19 months and huge volumes of grout, injected from the surface and from within the tunnel heading, to complete the last 180m of top heading, bench and invert.

To conclude the meeting with *T&TI*, Herdina explained that because of the various challenges the project's civil construction estimate of 2003 had increased by 15%. Time wise, he says that delays had pushed the opening date by a year, but that work was currently on schedule to meet the revised December 2012 opening date.

Meanwhile, planning and design of the Lower Inn Valley Phase II upgrade is progressing towards a start of construction in the second half of 2008 and when complete, Phases I and II of new rail through the Lower Inn Valley will contribute in no small measure to success of the Berlin-Palermo achievement. T&T



Left: Fig 2 - The 2615m H4-3 Stans section beneath the surface highway and railway required vertical jet-piling from the surface to create a ring of consolidated ground

Contributing editor, Patrick Reynolds, examines some of the remarkable accomplishments achieved during excavation of one of the world's largest rock caverns for the 450MW Kops II pumped storage plant, in Austria


Pre-stressing of the strand anchors prior topheading pillar excavation


Complex concreting works in the powerhouse cavern

Over-performing on Kops II caverns

In the period between November 2004 and December 2005, a total volume of 125,000m^3 was excavated to form the powerhouse and transformer caverns for Lot 3 of the Kops II Pumped Storage Scheme, in Austria. At the same time, excavation of associated tunnels and shafts (1782m in total) were also performed, amounting to a total of 78,000m^3.

Working to a fierce schedule, excavation techniques and site logistics were pushed to the limit. The level of lining works has also been remarkable. Over a period of 18 months, approximately 48,000m^3 of concrete was cast within the caverns, concurrent with the numerous lining and backfilling works in the tunnels, shafts and other auxiliary structures.

Project background

Scheduled for completion this year, the Kops II Scheme is currently being constructed on behalf of power producer client Vorarlberger Illwerke, in the Montafon Valley. With three 150MW rapid control power generation units to be used for turbine and pump operations, the plant will utilise the existing Kops Lake as an upper storage reservoir and the existing Rifa reservoir for lower storage.

All the major components of the scheme are located underground (fig 1), with a total investment cost in the region of US$535M. The construction works, which were divided into three lots, began in September 2004:

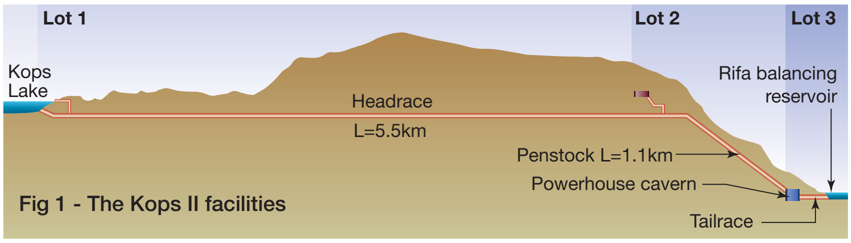


Fig 1 - The Kops II facilities

- Lot 1 - Headrace Tunnel. A 5.5km long pressure tunnel, forming the connection between Kops Lake and the pressure shaft, was excavated by the Swietelsky Tunnelbau/Torno SA/Torno Internationale JV. The a 5.54m diameter double-shield Robbins TBM utilised by the JV finished its drive in July 2006
- Lot 2 - Pressure Shaft and Surge Chamber. Awarded to the Swietelsky/Torno SA/Torno Internationale JV, the 1.1km long pressure shaft was also excavated by TBM, advancing from bottom to top. Featuring an inclination of 80%, the pressure shaft is 700m high
- Lot 3 - Powerhouse Cavern, Transformer Cavern, Tailrace Structure and Tunnel Systems. Constructed by the Jäger Bau/Beton- und Monierbau/Alpine Meyreder/Züblin JV, the powerhouse cavern is one of the largest engineered rock caverns to date. To accommodate the 38m-high generating units, the cavern is 88m long x 30.5m wide x 60.5m high, with an

excavated volume of approximately 113,000m^3. The transformer cavern, with an excavation volume of 10,000m^3, is 35m long x 16m wide and 19m high. The tailrace structure includes the inlet and outlet structure in the Rifa reservoir, a 267m long tailrace tunnel, a 31m high x 12m diameter tailrace surge chamber, plus a 47m-long chamber. Three pressure chambers, each 45m long, are linked to the tailrace via a 77m-long connection tunnel. In addition, a network of tunnels totals almost 1800m in length: Cross-sectional areas of 12m^2-52m^2, declines and inclines of up to 37%, as well as short tunnel lengths and numerous bifurcations, pushed conventional tunnelling to its technical limits and further hindered the already complex mucking logistics.

Geology and procurement

All parts of the Kops II project are built within the Silveretta crystalline rock series, consisting mainly of solid, hard strata, such as amphibolite, horblende gneiss and other types of gneiss, although some less solid mica schist was also encountered.

In general, the excavation benefited from favourable rock conditions, although rather more difficult ground conditions were met in some locations. Depending on particular rock mass quality, structural support of the excavations included rockbolts, shotcrete, wire mesh and steel arches.

Kops II was the first project in Vorarlberg that required an Environmental Impact Assessment (EIA) to identify and evaluate the impact of the scheme and look at possible mitigation measures. As a result, stringent requirements were placed on the client to ensure environmentally-friendly management and transport of spoil, as well as vehicle emissions, noise, and water pollution thresholds. Strict compliance with the various stipulations has been monitored by an independent environmental specialist throughout the construction works.

Cavern excavation

The excavation of the powerhouse and transformer caverns was complicated by various limiting factors, due in part to tender requirements and also to logistics. The bores began by using the existing pilot tunnel, which will become a cable tunnel in the operational phase of the project (fig 2). This had to be enlarged to provide space for two ventilation ducts and concrete mixer trucks. A 170m long muck removal tunnel, inclined at 24% and having a cross-sectional area of 22m^2, was also driven.

Branching off the pilot tunnel, a new access tunnel was built to open up the transformer and powerhouse caverns. Upon completion of the transformer cavern's top heading, the powerhouse cavern's top heading was excavated via two side drifts, access to the heading on the right being gained via a previously built cross passage.

Despite apparently favourable geological conditions, of predominantly compact gneiss and amphibolite, excavation was not an easy undertaking. This was due to a pronounced system of tectonic joints, with 100-200mm thick layers of mica schist, clay-mylonites and cataclasites, creating the risk of large sliding blocks. This required strict adherence to the defined excavation and support measures, especially in the 30.5m wide, gently vaulted powerhouse cavern.

The top heading of the powerhouse had a cross-sectional area of 220m^2 and was divided into three sections. The central pillar of the top heading was removed upon installation and pre-stressing of 43m long strand anchors in the side drifts, which had working loads of 1250kN. The initial excavation support employed after every advance consisted of Swellex anchors and reinforced shotcrete; while in the second round of advance, 16m long rockbolts and a second layer of shotcrete were installed.

Bench excavation within the powerhouse cavern

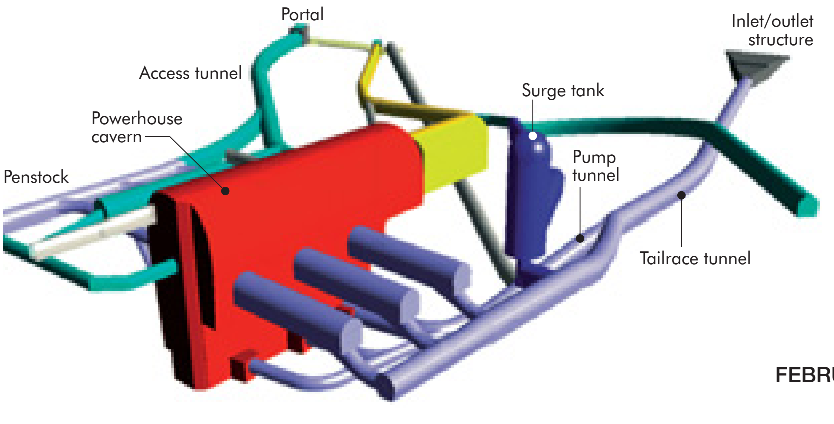
Due to the limited range of the lifting platforms, the heads of the strand anchors were capped with blast protection covers, and the second layer of shotcrete applied, before bench excavation was started.

Upon excavation of the first bench, concrete beams for a crane support structure were installed and subsequently supported by 68 strand anchors. The crane support was needed to mount the heavy-duty crane, which in turn would be essential for installation of the hydro mechanical equipment. To protect the concrete beams from possible damage from blast vibrations during the subsequent bench excavation, the concrete beams were placed on a 1.5m-high frame structure.

Spoil removal from bench excavation in the cavern was via a conical-shaped glory hole and a muck tunnel, with a rock crusher and discharge conveyor loading onto an 830m long by 800mm wide conveyor belt.

Geotechnical conditions made it necessary for the three large, compressed air surge chambers (each with a cross-sectional area of 66m^2) to be excavated and supported before each respective bench level was reached. The two remaining ground pillars – each 11m wide and located between the chambers – were strengthened by chamber-to-chamber anchors to reduce stresses and strains, thereby minimising adverse effects of load redistribution on the large cavern opening during excavation.

Originally, the pressure chambers were to be built via the muck and tailrace tunnel and a connection tunnel. However, construction logistics dictated that, instead, they should be advanced by three inclined tunnels running through the powerhouse, from the headrace to the tailrace system. The



Left: Fig 2 - Powerhouse and transformer complex at Kops II

Above and left: Excavation of the powerhouse and transformer caverns proved particularly challenging

pressure chambers were constructed at the same time as the crane beams in mid-2005.

A relatively low rock mass strength was observed when excavating the cable cellar of the transformer cavern. Despite extremely careful blasting works, the remaining vertical side walls had to be manually excavated and scaled in sections.

By the end of November 2005, all bench levels (10 in total) had been excavated. This was achieved despite the fact that, at the pressure chamber level, the bench height of 5m - the optimum to achieve a reasonable balance between drilling and blasting, mucking and support installation sequencing - had to be reduced to just half as much.

Also, unfavourable dipping and joints uncovered during blasting of the central bench section often resulted in sloping surfaces. As a result, wider side benches (drilled horizontally to help minimise overbreak) were required, at 5m-6m. This was up to 50% more than planned.

The remaining excavation works, such as dewatering pump sumps, local pits, and the tailrace tunnel, were completed by December 2005. The three inclined shafts for the pump mains were excavated top down, allowing the horizontal pump main tunnels to hole through when each respective bench level was achieved. For the tailrace, the tunnel was excavated below a road, river and dam. A 90m long soft rock section below the Ill River, towards the Rifa reservoir, was excavated using two groundwater lowering wells and pipe arch protection.

Cavern linings

At the tender stage of the project, the intention was that pumping was not to be used, due to the large quantities of concrete required in the caverns and expected high temperatures. However, it became evident that placing concrete by crane and bucket could put the construction schedule at risk. Additionally, the commencement of lining works in the powerhouse cavern coincided with the installation of the hydro mechanical equipment, and there was also limited use of the auxiliary construction crane. As a consequence, agreement was reached with the client to use pumpable concrete.

Two Putzmeister concrete distribution booms were employed to easily reach all parts of the powerhouse cavern. The concrete mix was modified and adjusted several times to keep the temperature low and minimise shrinkage cracking. An in-situ concrete mixing plant was also installed to allow independence and flexibility on site.

Another vital aspect of the lining works in the logistics-intensive environment of the powerhouse cavern, which was divided into seven activity levels each of which had 45 structural components, was to reduce the stock of formwork to a minimum. Using the standardised components of Peri's Trio formwork, the JV were able to efficiently cast slabs of up to 8.5m high and 4m thick.

The start of the lining works in December 2005 was also when construction work began on the first concrete foundations in the powerhouse cavern. The construction sequence was arranged so that the assembly/installation and concreting works were generally carried out in a staggered approach between the locations of the generation units. All other lining works were either done at the same time or - depending on the technical feasibility - had to overlap with the main lining works.

Works in the transformer cavern were scheduled to compensate for a longer interruptions or a total standstill of works in the powerhouse cavern. Key dates in the construction programme at the powerhouse cavern were influenced by the installation of the tailrace crane support structures and for operational start-up of generating unit no. 3.

Apart from the impressive dimensions of the structural components, which sometimes led to concreting times of more than 24 hours, the demands resulting from mechanical equipment installations were a major challenge. In particular, unlike previous projects, the steel structures such as bearings, rails and their structural components were concreted in one go.

Assembly of the steel reinforcement bars into densely packed, 3D cages for concreting was more time-consuming than anticipated. With numerous structural components being fully or partially lined with steel, ensuring accurate reinforcement arrangements called for intensive cooperation and coordination with the firms supplying the hydro mechanical equipment.

For project schedule reasons, all auxiliary structures had to be completed at the same time as the lining works of the powerhouse cavern. In addition to the concrete backfilling of the steel lining and the installation of concrete linings using shutters, the auxiliary structures to be constructed included several highly complicated transition and narrowing or widening sections. Formwork elements for those sections were produced on the project site and successfully installed. The 40m high surge chamber shaft was slipformed.

Surface challenges

A special challenge was the limited period available for surface construction works at the inlet and outlet structure in the drained Rifa lower reservoir. The time window to build the structure was the low water period between January 2006 and May 2006, as defined by the client.

However, a harsh winter saw temperatures drop to -15 °C and teams were pushed to their limits. With the frost zone extending up to 1m below the surface, the contractor used three to five layers of frost protection fleece to shield the concrete. As the date for the refilling of the Rifa reservoir was at the beginning of June 2006, postponement of the works was not an option.

At peak times, more than 130 skilled workers were on site and all works were performed continuously 24hrs/day. Overall, thorough preparation and the strong commitment of all the specialists involved has been key to the successful underground construction challenge at Kops II. T&T

ACKNOWLEDGMENTS

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The saga of “SkiLink 2020”

Dear Sir
It has been some time since I last corresponded with your organ, but the Swedish ski-run tunnel report in your November 2007 issue has prompted me to speculate on what might happen if a similar project was undertaken in the UK...

Following ten years of planning for “SkiLink 2020”, ground investigations, environmental impact studies, a public inquiry and three further years of detailed design, an engineer’s estimate of £50M is provided with a recommendation for further work. More ground investigation is ordered and two years of redesign ensues, resulting in a revised estimate of £75M. Both consultant and client lose their collective bottle and opt to procure a design-build contract with early contractor involvement. The cost escalates to £150M with at least three TBMs being required, together with a labour force of Cecil B DeMille proportions, oh yes, and another ground investigation.

In desperation an international project management group is brought in to urgently find cost savings. They immediately set about organising a four-week executive team-building exercise in Barbados and produce early results by convincing the architect that the pink marble cladding to the secondary cast iron tunnel lining is not an essential off-piste requirement. Unfortunately, costs continue to soar as a fire protection system and an emergency access service tunnel is included in the design by the consultant while the executive are in the Caribbean. Following much creative dining and several well-attended and catered workshops, it is decided that the best way forward is to re-brand the project “SkiLink 2100”, and there is general agreement that the new logo looks pretty cool.

Work on the tunnel finally begins but a nearby travellers’ camp soon complains to the local council that the state of the contractor’s worksite is lowering the tone of the neighbourhood. Tunnelling proceeds essentially without incident except for a large hole that mysteriously appears in the backyard of a crofter’s cottage. Over-mucking of the face is quickly discounted as the cause. The project is completed five years later at a cost of around £250M. A further six years is needed to sort out the extra £50M in contractual claims and a dozen assorted applications for worker compensation - including a badly bruised thumb and a nervous breakdown brought on by the combined effects of claustrophobia and the harsh language on site.

In all, the consultant trousers £10M in fees without a stain on his PI insurance, but now has nearly a hundred redundant graduate engineers to deal with. The client is put into administration and is eventually taken into public ownership, its chairman receiving an OBE and £2M severance agreement containing a gagging clause, before taking up his new appointment to manage the Kabul Metro project.

Delays and cost over-runs are blamed on NATM and abandoned water wells, whilst Q_{TBM} is updated to include an après-ski factor. The project wins a Carbon Trust award for its innovative approach to recycling the fifty tons of scrap paper generated by its quality assurance system and the new edition of the Tunnel Lining Guide is extended to cover the use of pink marble cladding. Despite strenuous enquiries by the police, no trace of one of the TBMs named “Shergar” is found after it mysteriously disappears on its way to site and no link with the eviction of the travellers by the council a week earlier can be established. Some years later, however, it is rumoured to have made an appearance at the Kabul Metro renamed “Poppy’s Prize”.

But it doesn’t end there, as the opening of the ski-run is delayed for two years pending the relocation of a colony of Pipistrelle bats that has taken up residence in the tunnel. Meanwhile, a legal action is brought by a poverty-stricken Earl who owns a stately home two miles away, where a 16th Century pane of glass fell out of a privy window during tunnel construction. A working group is set up to study ski-related tunnel injuries and an investigative report on the effect of the alarming growth in underground winter sports facilities on global warming is broadcast on national TV, prompting an enthusiastic but misinformed anti global capitalism sit-in at the tunnel. However, this is soon over after three cases of severe posterior frostbite, and several more of acute Nintendo-deprivation, are reported, resulting in a number of lawsuits being issued by the protesters.

Shortly after opening it is discovered the wrong kind of snow was used on the ski run causing another two-year closure as, sadly, someone forgot to keep the bats out whilst it was being replaced. On a happier note, a team of cable TV paranormal investigators conclude the stately privy is in fact haunted and the action against the contractor is dropped in favour of this more lucrative source of income. However, the protesters’ lawsuits are upheld by the Courts, citing the failure of a duty of care by the tunnel owner to provide adequate heated seats and games consoles.

Three years later the facility closes altogether, due partly to it being cheaper to fly Ryanair to Obergurgl, but mainly because of poor wheelchair access to the ski slope requiring costly modifications to the tunnel. Added to that, the working group concludes that a National Vocational Qualification entry requirement and a 2mph speed limit should be imposed on skiers in the tunnel. A recommendation the Health & Safety Executive endorses.

Another two years pass by and the tunnel reopens as a casino, thanks to Lottery funding and a generous donation by an anonymous Sicilian businessman based in Las Vegas to a charity of the Secretary of State for Culture’s choice, following an in-depth, fact-finding Ministerial visit to his Nevada ranch. This prompts an investigative TV report on the effect of the alarming growth in underground gambling facilities on global warming. The protesters return only to be enticed into to trying their luck at Texas Hold-em and manage to blow all of their compensation money.

In the meantime, a working group is set up to investigate the hand-arm vibration risk from the operation of one-arm bandits in a tunnel environment.

Yours ever
Drifter

“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@wilmington.co.uk

RMR and Q - Setting records

After 35 years of use throughout the tunnelling world, the RMR and Q classifications have proved themselves on numerous projects. They still face misconceptions however, as reflected in recent articles in T&T International. Here, Nick Barton, of Nick Barton & Associates, Norway, and ZT Bieniawski, of Bieniawski Design Enterprises, USA, clear common misunderstandings and provide the “ten commandments” for proper use of these rock mass classification systems

The RMR and Q rock mass classifications were independent developments in 1973 and 1974, whose common purpose was to quantify rock mass characteristics previously based on qualitative geological descriptions. They were originally developed for assisting with the rock engineering design of tunnels.

The value of thorough geological exploration was never disputed, indeed it was always emphasised. In addition, it was repeatedly stated that these classification systems were not “cookbooks” but had to be used for the purpose for which they were developed, as part of the engineering design process. This is clearly an iterative procedure in the case of underground works, where detailed knowledge of the ground develops from day to day.

At the time of the development of RMR and Q, geologists often worked in separate teams from those of engineers, leading to potential misunderstanding of what was required by whom, for engineering purposes. In fact, the advent of our rock mass classifications seems to have stimulated an opportunity to combine the efforts of engineers and geologists to act as one team, with clear statements of basic tunnel engineering needs and some carefully selected and quantitative geological data requirements. Needless to say, neither the engineering nor the geological parameters involved when using the two systems are exhaustive specifications in either the RMR or Q systems.

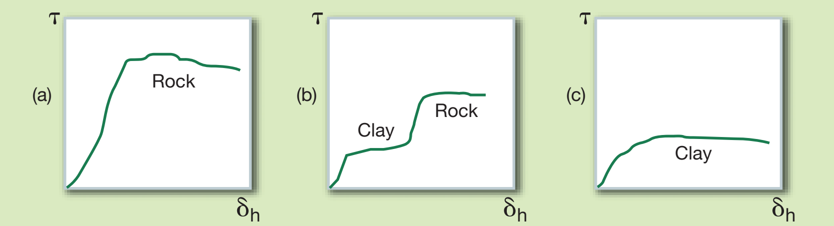
In essence, geologists should not be ‘afraid’ of quantified RMR and Q parameter ratings. The need for such quantification is perhaps appreciated more by certified engineering geologists who, although in short supply, do set an example to the traditional geologists, who are more the ‘free spirits’ of these basic earth science disciplines. Alas, the geological profession, even today, is not always in agreement on the scope of competence needed by engineering geologists.

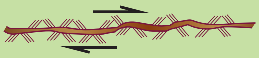
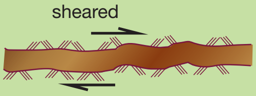
The scope of RMR and Q systems

The RMR and Q systems are particularly well suited in the planning stage of a tunnelling project when a preliminary assessment of the most likely tunnel support requirements is required, based on core logging, field mapping, and refraction seismics. In the case of plans for cavern construction, even details of location may be influenced by the results. During construction, application becomes even more essential, as the appropriate support classes are selected on a day-by-day basis.

It is obviously incorrect to state they play no role during construction or final design, as those involved more frequently in tunnelling consultancy will surely acknowledge. The reasons for this are as follows:

1) RMR and Q originated, and have been specifically updated, for estimating tunnel support. Later[1,2,3,4] they were extended for assessing rock mass properties, such as the modulus of deformation, interpreting seismic velocities, and for assisting with the interpretation of monitoring during



(a) Rock wall contact		(thin coatings)						
	Ja =	0.75	1.0	2	3	4		
	Jr	tan-1 (Jr/Ja)°						
A. Discontinuous joints	4	79°	76°	63°	53°	45°		
B. Rough, undulating	3	76°	72°	56°	45°	37°		
C. Smooth, undulating	2	69°	63°	45°	34°	27°		
D. Slickensided, undulating	1.5	63°	56°	37°	27°	21°		
E. Rough, planar	1.5	63°	56°	37°	27°	21°		
F. Smooth, planar	1.0	53°	45°	27°	18°	14°		
G. Slickensided, planar	0.5	34°	27°	14°	9.5°	7.1°		
(b) Rock wall contact when sheared		(thin fillings)						
	Ja =	4	6	8	12			
	Jr	tan-1 (Jr/Ja)°						
A. Discontinuous joints	4	45°	34°	27°	18°			
B. Rough, undulating	3	37°	27°	21°	14°			
C. Smooth, undulating	2	27°	18°	14°	9.5°			
D. Slickensided, undulating	1.5	21°	14°	11°	7.1°			
E. Rough, planar	1.5	21°	14°	11°	7.1°			
F. Smooth, planar	1.0	14°	9.5°	7.1°	4.7°			
G. Slickensided, planar	0.5	7°	4.7°	3.6°	2.4°			
(c) No rock wall contact when sheared		(thick fillings)						
	Ja =	5	6	8	12	13	16	20
	Jr	tan-1 (Jr/Ja)°						
Nominal roughness of discontinuity rock walls	1.0	11.3°	9.5°	7.1°	4.8^{a}	4.4°	3.6°	2.9^{a}

Above: Fig 1 - The parameters Jr and Ja are clearly related with ‘rock behaviour’, despite Goodman’s reference to Riedmüller’s doubts on this score. Other parameters used in RMR and Q are also clearly related to rock behaviour

straight

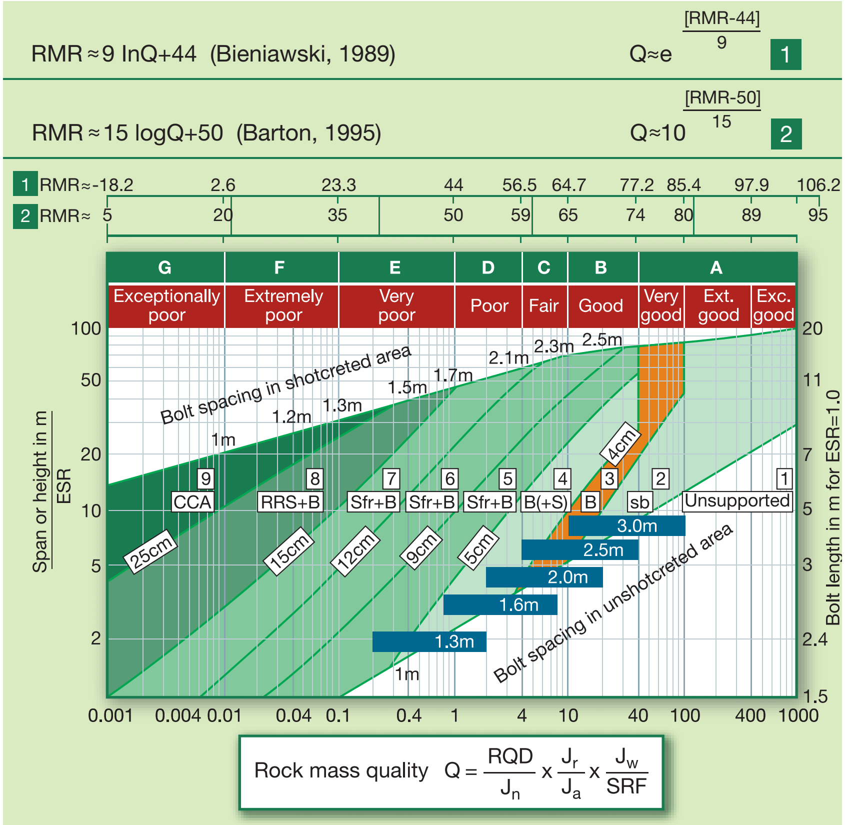
construction, via convergence-quality-tunnel-dimension links.

2) Estimating rock mass properties for numerical modelling has turned out to provide competitive alternatives to expensive and complex in situ tests, which rely on a number of assumptions for interpretation of the data. Significantly, plate bearing tests, large flat jack tests and pressure tunnel tests are nowdays rarely used because of their expense, and because of difficulties with disturbed zone phenomena. RMR and Q systems provide realistic estimates for modelling purposes, and through seismic measurement and interpretation[5], can assist in the interpretation of the disturbed zone characteristics.

3) Appropriate monitoring and recording of one or both rock mass classifications during construction is essential to quantify the encountered rock mass conditions, select the appropriate support class, and is useful in case of contractual disputes, arbitrations and design changes. Pells and Bertuzzi[6] will be aware of this, despite their preferred choice of applied mechanics beam theory for their tunnel and cavern design, apparently for seven of the nine Sydney cases they referred to from Australia. The support resulting from application of beam theory was reportedly heavier than stipulated by application of the Q-system, assuming that this was correctly applied. A further case record was used to criticise Q, where grouting of the rock bolts had been omitted, causing collapse in bedded sandstones: hardly a scientific approach for valid critique. Their reference[7], as supposedly supportive of their critique of Q, should be viewed with great care, since somewhat different agendas lie behind these two publications.

4) Technology has changed much in 35 years, hence support materials and methods must be modified. It is therefore that major updates have been made from time-to-time, such as the shift from mesh-reinforced to fibre-reinforced shotcrete[8,9] (see figure 2).

5) RMR and Q were found to be equally effective in very poor rock masses and in very good rock masses and it is incorrect to state that alternative descriptive methods might be preferable in poor rock mass conditions. As engineering geological techniques improve with advancing technology, our quantitative rating systems will always be preferable to qualitative descriptive assessments.



Above: Fig 2 - The support selection chart, from Grimstad and Barton[8] with the addition of alternate correlations between RMR and Q, from Barton[10]

6) Finally, both Q and RMR now form the basis of new TBM performance prognoses, in the shape of Q_{TBM}[10] and RME[11], which are developing both supporters and critics, as is only to be expected, in our challenging work-place.

Latest concerns

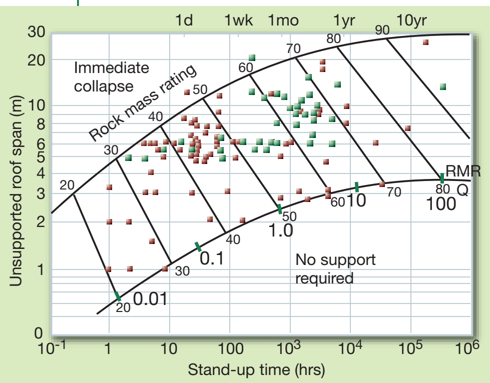
In spite of the above well-known facts, misconceptions and misuse of the RMR and Q systems surfaced in two recent articles in *T&TI*[6,12].

Goodman[12] paid respects to the late professor Riedmüller of Austria attributing to him the misgivings that: "...Engineers seem to be relying on generalised correlations of rock behaviour with rock mass ratings by Bieniawski's RMR and Barton's Q; yet the assignment of parameters is too schematic, the collection of data from exposures might not be adequately representative, and the assigned parameters are neither independent nor directly connected with rock behaviour."

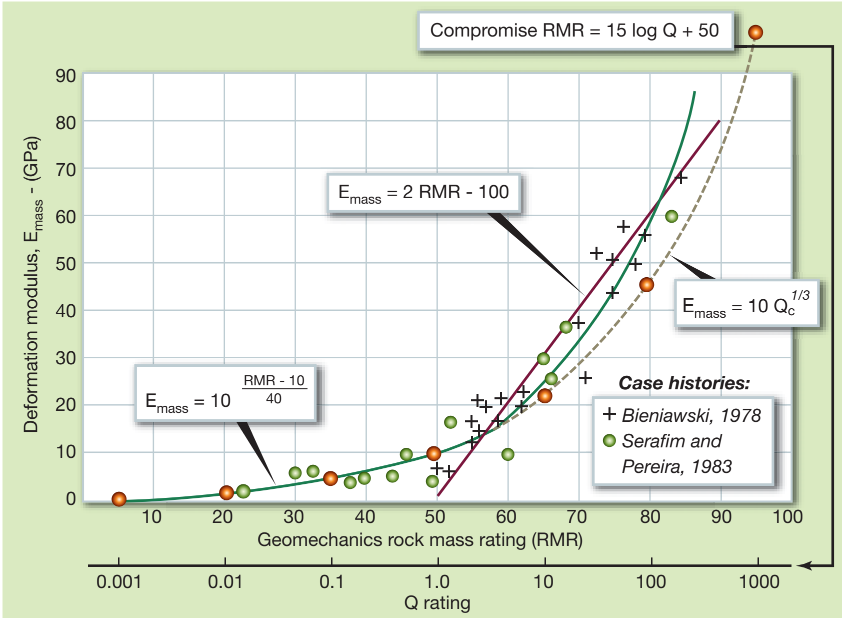
We are not sure which tunnelling projects were the source of Riedmüller's related concerns that... "quite a number of international case studies show that the importance of geological surface investigations is underestimated… or reduced to collecting the input data for a rock mass classification to be used for estimating support requirements" ...The authors of the RMR and Q methods have so much interaction with geologist and structural geologist colleagues that we have no hesitation in sharing some of Riedmüller's concerns. Geological surface investigations should be, and we thought always were, the essential forerunner of 'data collection from exposures', and of course dictate the location of subsequent boreholes and the interpretation of characteristics observed and quantified when core logging.

When using RMR and Q during construction, as of course is required, Riedmüller's concern that 'exposures might not be adequately representative' is only a

"WHEN YOU CAN MEASURE WHAT YOU ARE SPEAKING ABOUT, AND EXPRESS IT IN NUMBERS, YOU KNOW SOMETHING ABOUT IT; BUT WHEN YOU CANNOT EXPRESS IT IN NUMBERS, YOUR KNOWLEDGE IS OF A MEAGRE AND UNSATISFACTORY KIND."
LORD KELVIN (1824-1907)



Aboce: **Fig 3 - Stand up time data versus RMR from case histories after Bieniawski[2]. Conversion of RMR to Q after Barton[10]. Red represents tunnel, and green represents mine results**



Above: **Fig 4 - Static modulus of deformation Em versus RMR and Q. Case histories and RMR data compiled by Bieniawski[1], Q relationship by Barton[3]**

temporary limitation (of any data collection activity, including structural geology).

We certainly dispute that 'the assigned parameters are neither independent nor directly connected with rock behaviour'. We are quite sure that Riedmüller, his frequent co-author Schubert, and of course our respected colleague Goodman, were and still are, extremely aware of the importance of such features as joint and discontinuity characteristics, in determining both shear strength and swelling potential. Since stress in relation to strength, and joint spacing and number of joint sets are additional parameters in the two classification systems, it is hard to see that Riedmüller can really have believed that ...'the assigned parameters are neither independent nor directly connected with rock behaviour'. If true, then he must have partly misunderstood their structure and purpose.

For instance in the Q system, the parameter pair Jr/Ja gives a very close approximation to the coefficient of friction, as measured in numerous in situ shear tests of filled discontinuities (figure 1). These two parameters, though independently acquired, in combination reflect realistic magnitudes of shear resistance to overbreak and general instability. This part of the Q-value is also sensitive to the details of shear resistance, with φ+i, φ, or φ-i, in the three contact categories, representing dilatant, non-dilatant, or contractile shear behaviour. Of course such details are 'directly connected with rock behaviour' around tunnels. So we respectfully disagree, and wonder why this lack of understanding has developed. Why would so many, presumably intelligent people, develop and apply such systems in very many countries, if these concerns were founded in reality?

A month after Goodman's contribution, another concern was expressed by Pells and Bertuzzi[6] that: "Classification systems are good for communication... but... should not be used as the primary tool for the design of primary support. Q and RMR values are not factual data in respect to the engineering geology of the rock mass; they include a significant degree of interpretation. Therefore, they should not appear on engineering geological logs of boreholes or on records of line mapping of excavations."

It is hard to counter critique of the classification systems from those who either have other agendas, or who prefer the mechanics of beam theory for designing tunnels and caverns in a medium as variable and complex as rock. Our first reaction is to wonder how many engineers share the above conviction that this is the way to go.

Indeed, Q and RMR 'include a significant degree of interpretation', but it must be hoped that this would also apply to the application of beam theory. It is remarkable that Pells and Bertuzzi[6] should be so against 'main stream' engineering geology and tunnelling practice, to advise that Q and RMR values 'should not appear on engineering geological logs of boreholes and on records of line mapping of excavations'. When so obviously conflicting with convention, their publication is a surprise.

'Ten commandments' for using RMR and Q

To avoid confusion, we would like to offer "ten commandments" of broad principles for proper use of our rock mass classifications:

I) Ensure that the classification parameters are quantified (measured, not just described), from standardised tests, for each geologically designated structural region, employing boreholes, exploration adits and surface mapping, plus seismic refraction for interpolation between the inevitably limited numbers of boreholes.

II) Follow the established procedures for classifying the rock mass by RMR and Q and determining their typical ranges and the average values.

III) Use both systems and then check with at least two of the published correlations of Bieniawski[2] and Barton[4].

IV) Estimate support and rock reinforcement requirements (figure 2). The Q-system supplies permanent support, but only if the components B adn S(fr) are of good quality.

V) Estimate stand-up time (figure 3) and rock mass modulus for preliminary modelling purposes (figure 4). A stress-dependent modulus may be needed if depth is significant[4,5].

VI) Perform numerical modelling in appropriate cases (large spans, special conditions) and check if sufficient information is available.

VII) If sufficient information is not available, recognising the iterative design process, request further geological exploration and parameter testing, e.g. stress measurements, if necessary.

VIII) Consider the construction process, and in the case of TBM feasibility studies, estimate the rates of advance, using the Q_{TBM} and RME methods.

IX) Ensure that all the rock mass characterisation information is included in the Geotechnical Baseline Report, which discusses design procedures, assumptions and specifications.

X) Perform RMR and Q mapping as the construction proceeds so that comparisons can be made of expected and encountered conditions, leading to design verification or appropriate changes.

Of course, it goes without saying that laboratory tests must be included and performed diligently according to standardised procedure and with a sufficient budget. The engineers and geologists should act as a team and communicate regularly among themselves and the client.

"IT IS NOT THE THINGS YOU DON'T KNOW THAT GET YOU INTO TROUBLE. IT IS THE THINGS YOU THINK YOU KNOW FOR SURE." SIR WINSTON CHURCHILL

Conclusion

After 35 years of use throughout the world in tunnelling and mining, the record of the RMR and Q systems in geological and engineering practice speaks for itself. These two systems have become entrenched as the most effective empirical design tools for determination of rock mass quality and estimating rock mass properties and tunnel support measures.

However, it is prudent to apply these classifications in the letter and spirit for which they were developed, and to learn from corroborative case histories.

Let us conclude with this applicable wisdom: "It is not the things you don't know that get you into trouble. It is the things you think you know for sure." (Attributed to Sir Winston Churchill) T&T

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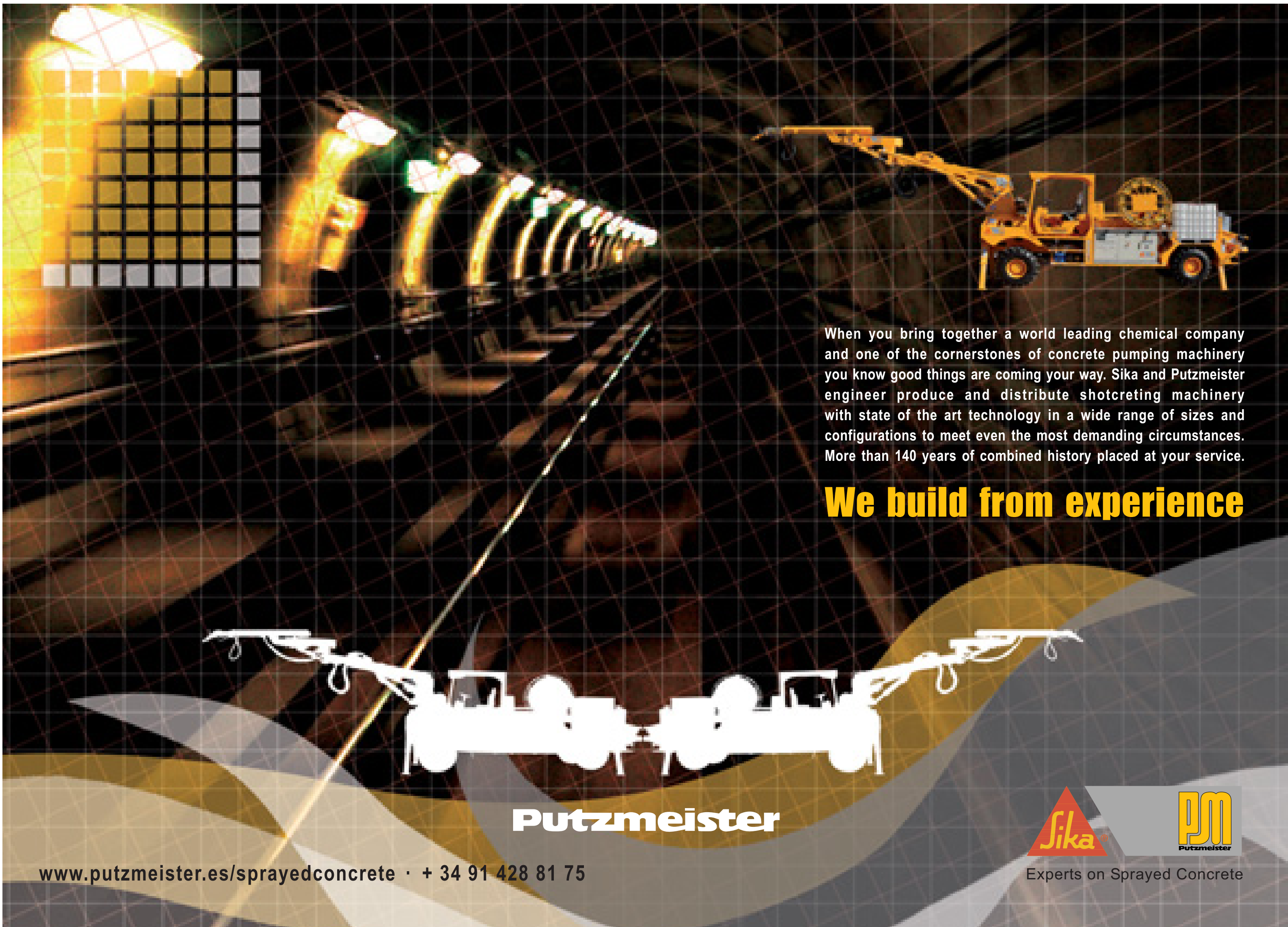


Communication to avoid costly repeats

Dear Sir
I read the letter "A problem shared" (*T&TI*, November 2007, p37) with mixed feelings. Having been associated with the project, albeit in a minor way only, my main concern relating to this dowel/insert miss-fit was that there was a repeat of the identical occurrence experienced by the Hong Kong tunnel team using the same equipment!!

I am sure that the Durban team much appreciated the rapid assistance given by David Salisbury and his team, but this would never have been necessary if the lesson learnt from Hong Kong had been made available to the public domain. This was surely the point of the editorial - the industry is not good at passing on information, or learning lessons relating to problems experienced, thus preventing totally unnecessary and potentially costly repeats!!

Whilst it was refreshing to read of the lessons learnt on the Singapore DTSS tunnelling contracts (*T&TI*, October 2007, p23), again I was somewhat surprised that the wealth of information available from the Land Transport Authority metro tunnelling was not referred to, in order to avoid the plethora of TBM problems reported.

It is to be noted that in the same issue (p17) the Japanese were fully prepared for the potential problems in constructing (very successfully it seems) the Tokyo Bay Gas Pipeline tunnel. This approach should be common to all projects, where possible, and would surely make our tunnelling industry considerably more efficient and attractive to potential clients?

Yours faithfully
Neville Harrison FICE
Consultant to MM

OBITUARY

Alan Cox

It is announced with sadness that Alan Cox died suddenly in mid-November last year. Alan spent his whole working career in the tunnelling industry, mainly as a TBM design engineer and latterly as a TBM advisor.

Alan joined Robert L Priestley in 1953 as an apprentice draughtsman and advanced to the position of chief design engineer.

Following the closure of Robert L Priestley, Alan joined Grosvenor Tunnelling, which was a part of the Davey Group. He worked as senior design engineer and commissioning engineer on a number of TBM projects including the Warangoi Hydroelectric Scheme in Papua New Guinea, the Greater Cairo Wastewater Scheme, in Egypt, and the Singapore Mass Transit System Phase 1.

Following the purchase of Grosvenor by James Howden, Alan became project manager, assisting the team in the development of the four Channel Tunnel TBM's, four EPB TBM's for Denmark's Storebaelt Link and several other mass transit systems.

In 1990 Alan formed his own consultancy to assist clients, contractors and TBM manufacturers with his tunnelling knowledge. He was employed on many major projects, including London's Jubilee Line Extension Contract 105, where he was TBM advisor to London Underground Limited looking after the operations of four Kawasaki EPB TBM's.

Most recently he continued this role in assisting the client as TBM advisor on the UK's Channel Tunnel Rail Link, where he assisted with the specification and operation of the four TBM drives from the Stratford Box.

Alan was a very well trained engineer who learnt from his experience, developed over a career in tunnelling, his humour was well known and his manner always friendly.

He will be sorely missed by his wife, Marion, and by all his friends within the tunnelling industry.

Alan Cox will be missed by friends and colleagues within the industry

Dispute avoidance through settlement

For reasons of cost and commercial good sense, it is usually preferable to reach a settlement agreement than enter a formal dispute process. T&TI's contracts and disputes correspondent, Paul Cullinan, of Plus 3 Consultants, provides some guidelines for the best approach to the process

Whilst lawyers and claims consultants may get very excited about the minutia of dispute resolution - not to mention their fee stream that comes with it - for the parties involved a dispute is only ever a disruption to their business of procuring or constructing tunnels. Any sizeable dispute will be a significant drain on what will likely be senior management resources on both sides. Even in a formal dispute, it is very unlikely there will be any recompense for this resource and more importantly it distracts from the management's primary tasks of creating new business and delivery of ongoing projects.

For the above reasons and those of pragmatism the best course is often for parties to settle without recourse to formal procedures. In practice this is in any case how a majority of disputes will be resolved.

Formulation of the dispute

Whilst settlement is intended to reduce the amount of time, energy and money invested in reaching a resolution rather than entering into a formal dispute, the preliminary steps in formulating and reviewing claim submissions should be the same, whether this be in the valuation of variation items or submissions for additional time and/or money arising out of delay and disruption to the works.

A well-formulated submission gives both parties an opportunity to come to a realistic assessment of their respective entitlements and liabilities. Providing clarity as to the legal and contractual bases upon which that entitlement is made, and logically linking those principles to a rational assessment of the losses suffered, should assist both sides in evaluating where any strengths and weaknesses lie. A poorly formulated claim with submissions made on indistinct legal bases and global assessments of loss leads to confusion and suspicion of 'claimsmanship', and in short, to a very bad start for any settlement negotiations.

Exchanges

Following submission of a claim there should typically be an opportunity for the receiving party to have time and opportunity to review its contents and respond with any observations as to principle or quantum. Apart from this process starting to give some shape to the parties' respective positions, it is in any case a pre-requisite, even in formal dispute process, that the claiming party notifies the receiving party of the details of the case being made against it before a dispute can be said to exist.

Risk assessment

Before beginning any settlement negotiations each side should undertake an internal risk assessment and peer review of the claims made. Risk assessments need not be of any complicated Monte Carlo-type, although some organisations may have the specialist knowledge and capacity to undertake such advanced techniques. More usually what is required is a consideration, in turn, of the individual heads of claim. The process will be made more accessible and meaningful if the points made above regarding the logical formulation of the submissions have been adhered to.

Each head of claim should be reviewed, firstly applying a percentage likelihood of success of the legal and contractual principles involved, followed by a separate review of the quantum attached to each principle. The product of this two-part assessment will give a percentage likelihood of success of each head. The process is repeated until risk assessed figures have been arrived at for all heads and a total reached. Ranges of percentages can be used in the consideration of each head, this will give an eventual risk assessed upper and lower limits of settlement. This latter approach can be desirable when reporting to internal management, as giving a range conveys the necessary degree of approximation, which is the nature of a risk assessment.

The influence of personalities

Many disputes are often driven by strong personalities on both sides. The complex and technically challenging environment of completing underground works can sometimes mean that they are driven by shear force of personality. It is likely therefore that there will be few ‘wallflowers’ in the senior management of both the contracting and client side of any project. This otherwise desirable attribute can mean such personalities might not be best suited to making the necessary dispassionate assessment of entitlement and liability, which is an essential prerequisite if the matters at odds are to be resolved short of a formal dispute process.

It is for these reasons that the risk assessment should be carried out in the manner of an independent peer review. This may be by a senior person from within the organisation who has been unconnected with the project, or better still by external advisor who themselves are strong enough to give realistic dispassionate advice. In this way the conclusions reached can be de-personalised, objective and provide a more sound basis for what is essentially a business decision-making process.

“GREAT CARE MUST BE TAKEN IN DRAFTING THE AGREEMENT, AS ANY MATTERS THAT ARE NOT EXPRESSLY DEALT WITH WILL BE SWEPT UP IN THE GENERALITY OF THE AGREEMENT”

Negotiations

There can be no ‘formula’ for the conduct of negotiations themselves, these will be dependent on the scale and subject matter of the claims themselves, the stage of completion of the project, and very probably the contribution and interaction of the aforementioned personalities. There will inevitably be some tactical gamesmanship centred around one or other of the parties wishing to approach matters on an issue-by-issue basis (known as salami tactics) or approaching all issues on a broad front in order to achieve an overall settlement without being seen to make admissions in respect of any particular issue.

What should always be clear however is that the negotiations are being made ‘without prejudice’, that is, without prejudice to the positions of the respective parties in the event that settlement negotiations fail and resort has to be made to a formal dispute process. A clear understanding of without prejudice basis of any discussions should also assist in promoting a degree of openness that may assist resolution.

It should be obvious those attending any negotiations have the authority to make agreements, or at least it be made clear the extent to which any representatives need clearance from other management or their board, before a deal can finally be struck.

The settlement agreement

The outcome of a successful negotiation should be an agreement that encompasses the matters that were in dispute. If the settlement is after completion of the works then it should ideally include all matters pertaining to the project so that further management time is not expended on returning to matters left in abeyance at some future date. Careful attention needs to paid to the drafting of the settlement agreement itself. It is not unheard of for much time, energy and legal fees to be expended in trying to ‘unpick’ a deal, which has later been seen as unfavourable.

The legal status of any settlement agreement will be that it replaces the underlying contract as the basis of the bargain between parties, the settlement is in effect a new contract and it is the binding force of that new contract, which in the event of any reneging of the deal can be presented to the courts for enforcement. In this respect it should be noted that the without prejudice status of negotiations falls away with the final agreement. In that eventuality, the courts will interpret the settlement agreement in the same way they would any contract, which is an objective interpretation of the intention of parties based on the words of the document.

Great care must be taken in drafting the agreement, as any matters that are not expressly dealt with will be swept up in the generality of the agreement. For example, a settlement agreement for the payment of a lump sum by the Employer will, without any express provision to the contrary, be deemed to include for all releases of retention and taxes payable within the amount of the lump sum. So that, if it is the Contractor’s intention that retention and tax are to be dealt with outside of the lump sum, then the agreement should be clear on this.

It would be rare that a settlement agreement would include the Employer’s abandonment of his contractual right to the remedying of work defects and again, if this is the case, then the settlement agreement should be clear. This can readily be done by a term stating that the provision of the original contract should apply in this regard.

Third Party Actions

Another important aspect of drafting the settlement agreement, though probably only for the Contractor, is that the whilst there may be compelling reasons to reach a wrap-up agreement by way of an undefined lump sum with the Employer, in many instances the root causes of the claim may well be the liability of third parties, such as the Contractor’s sub-contractors and suppliers. Difficulties begin to arise then in claims that the Contractor may, in turn, make against those third parties; in that he will not be able to show with the required precision which parts of the lump sum pertain to the matters claimed against individual third parties.

The law in England recognises, in principle at least, that settlement agreements reached in head contracts can be used as evidence of loss in claims further down the contractual chain. This long-standing policy is based upon the desirability that cases should be settled rather than pursuing all the way through the court system and a recognition that a party may be dissuaded from reaching such settlement if it compromises its claims against third parties.

The leading case on the matter being that of Biggin -v- Permanite [1951] 2 KB 314, CA. In the more recent case of Bovis Lend Lease Limited -v- RD Fire and Others [2003] EWHC 939 (TCC), His Honour Judge Thornton extracted various principles from Biggin, which included:

"As a starting point, a claimant may recover the sum paid in settlement if it can establish that that settlement was reasonable and that it was reasonable to settle the third party's claim. It is only necessary for the claimant to prove, in general terms, that the settlement was reasonable. It is not necessary for it to establish in great detail the extent and quantum of the third party's claim."

Whilst this may sound like a charter for a contractor to simply settle his upstream claim and then deduct the sum settled from his sub-contractor/supplier's account, HHJ Thornton went on to say:

"IN MANY INSTANCES THE ROOT CAUSES OF THE CLAIM MAY WELL BE THE LIABILITY OF THIRD PARTIES SUCH AS SUB-CONTRACTORS"

"The claimant must establish by normal methods of proof and to the normal standard of proof that the defendant was in breach of contract and that that breach caused the claims to be made. Equally, it must establish that the defendant's breaches of contract led to breaches by it of its contract with the third party."

[In this case the claimant is the Contractor, the defendant is the Sub-contractor/Supplier and the third party is the Employer]

It may therefore be that for the Contractor's purposes something more detailed than a single lump sum needs to be shown in the settlement agreement between him and the employer to evidence the various losses he may then want to recover from sub-contractor/suppliers. This however is very delicate ground, as any collusion between the Employer and Contractor in their settlement agreement to 'finesse' certain figures to assist the Contractor's recovery down the chain, could possibly be framed as conspiracy to defraud the sub-contractor/supplier.

Settlement during formal disputes

It should be borne in mind that even if a formal dispute process is begun efforts at a settlement should be continued by the parties and their representatives. Arbitration and litigation will offer various stages at which it is prudent to at least undertake a review and new risk assessment of the state of play at that particular point. For instance, once pleadings are exchanged each side will have a better idea of the strength of the others case being made, which may alter perceptions of the likelihood of success. Parallel, without prejudice discussions can be had at any point during a formal process.

Conclusion

For cost, commercial good sense and in the interest of continuing relationships it will, generally, be preferable to reach a settlement agreement than enter a formal dispute process. However, settlement discussions should be approached in a structured manner so as to understand what would be a good or a bad deal and the terms of any agreement so reached should then be captured in a properly drafted settlement agreement. T&T

Isolating the ILW shaft at Dounreay

At November's British Tunnelling Society meeting, Alex Tiernan, project manager, and Iain Robertson, site manager, for Ritchies a division of Edmund Nuttall presented the challenges on the Dounreay ILW Shaft Isolation Project, part of the UK's Nuclear Decommissioning programme

Above: Original shaft during construction

The Dounreay ILW Shaft Isolation Project arose from a long-term problem, which had been in existence since 1977. At that time, disposal of Intermediate Level Waste (ILW) waste into the shaft, which formed part of the Liquid Effluent Discharge Tunnel (LEDT), created an explosion in the head space above the waste column (figure 1), effectively ending waste disposal.

The history of the LEDT goes back to 1954, when the tunnel was constructed using the shaft in question as a temporary access shaft. In 1958 the Scottish Office granted authorisation for the disposal of radioactive waste for one year and in 1959 the facility was licensed as an Interim Level (radioactive) Waste (ILW) disposal facility.

This disposal facility continued to operate through into 1971, when routine disposal ceased other than for items that were too large to fit into the new silos erected on site.

It wasn't until 1988, some 11 years after the explosion, that "In-situ Confinement" of the material in the shaft was adopted as the long-term strategy. In 1995, with concerns mounting over the lack of a suitable waste strategy for existing nuclear facilities, the long term strategy for Dounreay ILW Shaft was changed to "Retrieval of Waste".

From 1990-1994 various waste retrieval options were considered and it was concluded that retrieval should utilise the archaeology dig approach, whereby individual items would be identified and removed by remotely operated robotic or grab equipment. There were two sub-options, in that the retrieval could be carried out as wet or dry retrieval. However, both required groundwater around the shaft to be controlled as an essential element of the retrieval process (figure 2).

The options for shaft hydraulic isolation were numerous and included:

- Do nothing - discounted on the grounds that costs would be in excess of US$450M, due to the need to treat the groundwater inflow of 350m^3/day
- Just in time ground water control - discounted on the same grounds
- Ground freezing around the shaft - again discounted due to cost and energy requirements, and the problem of securing the freeze beneath the shaft
- Cut-off wall - discounted due to cost and difficulty of sealing below the shaft
- Grout curtain - installing a grout curtain around the shaft that would reduce inflow to no more than 15m^3/day when the shaft was empty

The final agreed solution was the grout curtain and Ritchies and Skanska were each awarded a pre-tender contract to undertake preliminary modelling and material selection.

This work lead to a contract for the installation of a grout curtain being awarded to Ritchies in 2004. The Contract was let as a Design and Build NEC Option C contract and included:

- Installation of extensive geotechnical monitoring equipment
- Extensive field trials to demonstrate the final design
- Design life of 45 years (post retrieval and remediation)
- Inflow capped at 15m^3/day when the shaft is empty
- Development of robust testing and validation proposals
- Completion in summer 2008

Preliminary pre-tender modelling indicated a 10m wide barrier would be required and a mass permeability of 10^{-8}m/s to achieve the stated discharge. Preliminary material analysis indicated that:

- Blocker and Primary grout would be ultrafine cementitious grout
- Secondary grout, if required, would be non-particulate grout

Initial pre-trial design work, carried out on behalf of Ritchies by Halcrow, was influenced by recent Scandinavian experience that showed success using cementitious grouts only, providing good penetration into rock using thick stable ultrafine grout mixes.

Grout penetration was considered to be dependant on a few key liquid grout parameters with the target aperture defined by fracture flow characteristics. As part of the pre-trials design there was a need to:

- Design and test suitable grout materials and mixes
- Develop batching techniques
- Commission drilling equipment

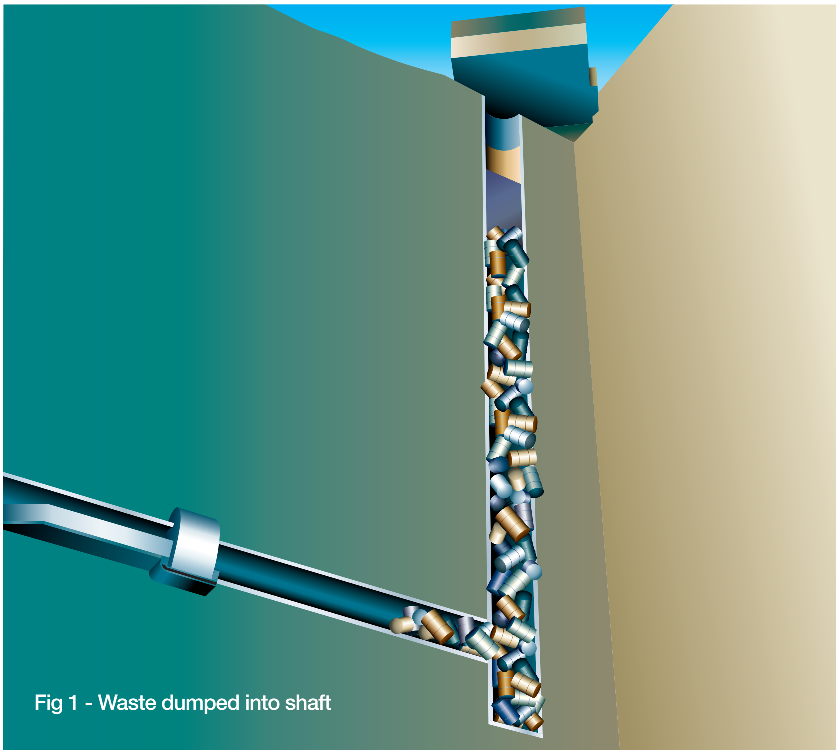


Fig 1 - Waste dumped into shaft

- Develop injection techniques
- Demonstrate desired grout penetration
- Define controlling Grout Intensity Number
- Construct a full-scale trial barrier for validation purposes

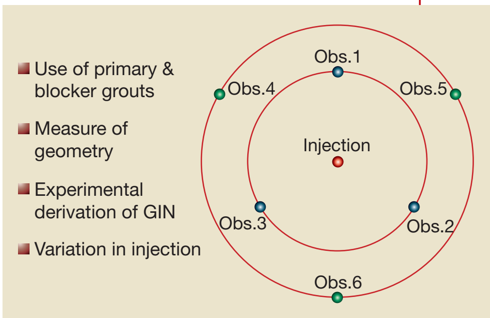
For the material design a large number of trial mixes were undertaken to develop the right properties of the grout for the full-scale barrier trial. This testing took four months and covered six primary cement candidates with multiple additives.

Overall over 200 mix designs were trialled, with over 10,000 index tests performed, and at the conclusion it was found that a 16 micron cement gave the best results. All of the testing was undertaken on site and at Ritchies UKAS Laboratory, in Kilsyth.

For the full-scale field trials a geologically similar area was chosen, along the same strike as the shaft unit, close to the cliff line and with both similar stratigraphical sequence and structural geology.

Prior to commencing the trials, extensive ground characterisation was carried out comprising extensive geological and hydrogeological investigations of the trial area, hydrotesting and geophysical logging, VW piezometer suites installed, and preliminary pump tests carried out in the zone of the demonstration barrier.

With this work complete and following commissioning tests on all the equipment the trials began. Initial penetration testing was carried out as shown on figure 3 and



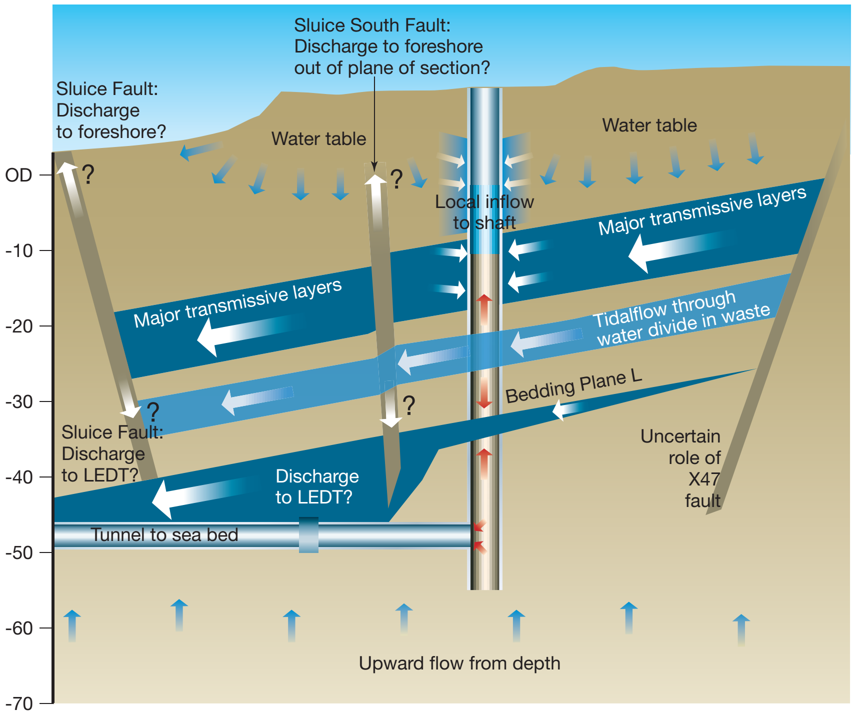
Above: Fig 3 – Trial penetration testing

then the full demonstration barrier trial proceeded. The barrier was made up of a series of injection points providing a series of interlocking grout spreads building up to the full 10m barrier (figures 4 and 5).

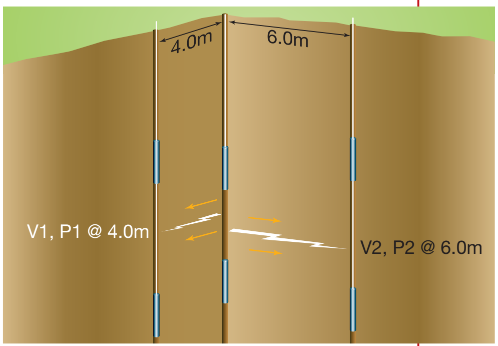
To record how the grout was flowing pH was measured in observation holes and the changes noted, thereby giving data that could be developed into a flow/grout programme.

All the drill holes were cored to minimise the production of radiologically contaminated waste. The drill flush water from the rigs was recycled through a solids treatment plant, meaning the same flush water was used for eighteen months.

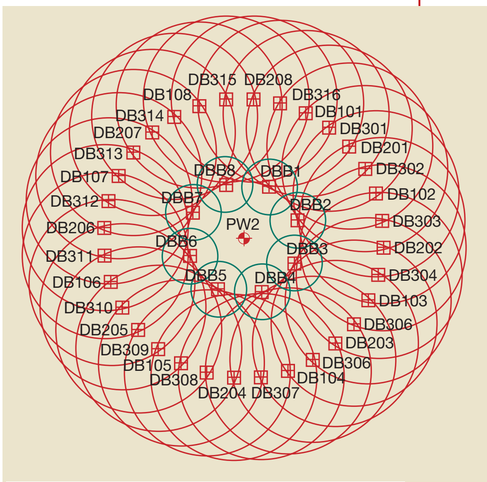
The drill holes were required to be drilled to a verticality of 1:100 in order to maintain the correct hole spacing.



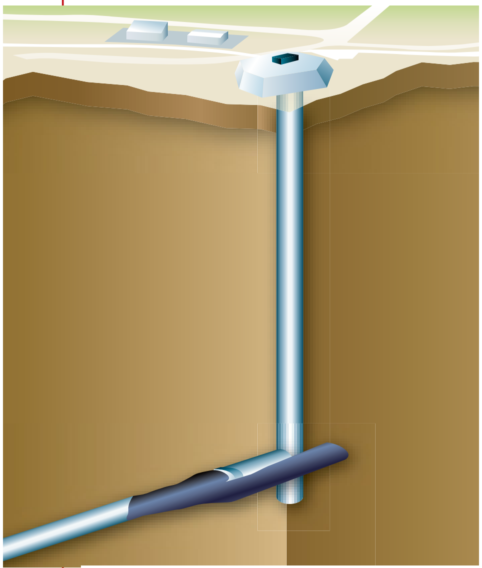
Above: Fig 2 - Groundwater flows around the shaft



Above: Fig 4 - Penetration testing set-up



Above: Fig 5 - Field trial barrier



Above: **Fig 6 - LEDT Infill section**

Shaft working platform

During the trial it was found that the holes deviated slightly, with the direction of deviation controlled by the geology (deviation direction always up-dip).

The grouting plant was equipped with full data logging facilities and during operations the plant produced 100MB of raw data per week. To manage this data three engineers were employed full time.

Having completed the field trial demonstration barrier, pumping tests and high-specification packer tests were used to validate the impermeability of the barrier as installed. The main findings were as follows:

- Field trial was successful
- 10^{-9}m/s achieved with cementitious grout
- CS grouts inject easily at this permeability
- Controlled use of pressure beneficial
- Upper weathered zone challenging and need different approach
- Barrier performance controlled by internal surface area

The implications for the main works were that there would need to be a revised grouting methodology for the weathered zone, that 'real-time' monitoring should be utilised to monitor ground movement and that a revised geometry would be utilised, namely a boot shape, to minimise the internal surface area of the barrier while providing continuity of the barrier around the base of the shaft.

With the field trials having been completed, preliminary works commenced. With the shaft being situated virtually on the coast, it was necessary to construct a mass concrete raised working platform. This platform was built around the shaft head and was sufficiently large to ensure that operations could be carried out at all tide levels and in most weather conditions.

With the platform constructed, extensometers and VW piezometer instrumentation was installed and a sonar survey undertaken of the LEDT to map the as-built dimensions of the tunnel, identify the locations of the discharge pipe bundles within the tunnel and confirm the location of the stub tunnel plug, which separates the shaft from the operational LEDT tunnel system (figure 6). This information was required to optimise grout hole location and allow accurate tracking of grout infill progress against the theoretical volume.

The LEDT grouting required a special bulk fill material with a permeability of 10^{-9}m/s and a strength of 10N. In addition the material needed to be low-heat to reduce shrinkage as well as anti-washout, thixotropic, flowable and no-bleed.

The grout was required to have an expansive capability at 50m head and extensive trials over four months utilising seven different components were required before a suitable mix was obtained

Having completed grouting of the LEDT, work commenced on the barrier grouting utilising a series of injection holes and repeated stages of grouting.

The equipment as previously described is highly sophisticated and relies heavily on computerised systems and data-loggers, all of which are supervised from a central control room. In addition to the measuring of the grouting operation it was necessary to measure ground movements, so a series of multi level extensometers were installed for this purpose.

These extensometers are up to 100m deep and are sensitive to 20microns and accurate to 50microns.

As a result of the mass of data recovered from the exercise to date, it has been shown that the drilling does induce movement. Equally interesting is that the movement recovers during changing of the core barrel.

As of November 2007, some 20km of drilling and grouting has been completed, with some 4km still to be undertaken. There are also still a number of challenges in dealing with drilling induced ground movement at the top of the shaft. This will be followed by an extensive validation exercise that will seek to confirm that the groundwater inflow will be contained within the 15m^3 per day required. This validation exercise will be exhaustive as it is not intended that the shaft will be dewatered until the retrieval process commences sometime in the distant future.

In closing, the speakers thanked the client for its support in the implementation and execution of the scheme to date. T&T

QUESTIONS FROM THE FLOOR

Bob Ibell (London Bridge Associates) asked if there were any problems working on a contaminated Nuclear site.

Alex Tiernan replied that all workers wore protective clothing, which was changed daily. Daily radiological measurements were also taken. This tends to reduce the progress of the works, but as the goal is to carry out the works safely and to achieve the barrier as required time is not the driver.

Mike O Connell (retired) asked what contract terms had been used for the trials.

Tiernan advised that NEC Target cost Option C had been used and with an understanding Client the Target Cost had been increased through discussion and implementation of compensation events as works proceeded.

Dai Heycock (retired) asked if any grout had leaked into the shaft during the grouting operations.

Iain Robertson responded that the pH of the water in the shaft was regularly checked and to date this suggested there was minimal contamination from grout ingress. In addition there is CCTV coverage of the shaft head and only very minimal ingress had been detected.

A further question was raised from the floor regarding some of the pH readings shown as part of the presentation, which indicated there might in fact be contamination in the shaft.

Robertson responded that a one-off error had been found in the lab results and current inflow is being investigated, which might lead to the possibility of some additional works being carried out in the top of the shaft. Within the shaft platform there is a culvert, which had recently been found to be full of water and may allow leakage into the shaft. This is now being dewatered.

A final question raised the possibility that the shaft was still generating hydrogen and therefore there was still a risk of explosion.

Tiernan confirmed that this was still on the risk register

Rapporteur: David Court

Products

Forming cost-effective avalanche protection

Due to numerous avalanches in recent years, the 300m long Untergrimming avalanche protection gallery, near Bad Mitterndorf, in Austria, has recently been extended by a further 115m.

For cost-effective construction of the nine concreting sections, each with 14m standard cycle lengths, the contractor, Östu-Stettin, is using a Peri formwork solution based on the Variokit construction kit. Through the use of standardised and rentable series production components, it has been possible to almost completely eliminate special elements. This has meant the overall costs have been greatly reduced – particularly with regard to the small tunnel length and the short construction period.

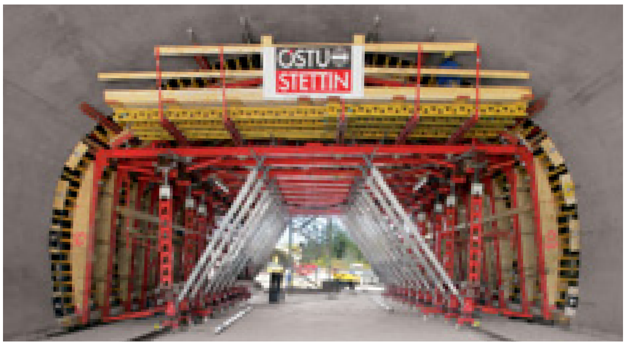
Using cut and cover methods, the 12.8m wide cross-section has been designed for three lanes and is concreted in a single operational sequence. The 600mm thick tunnel arch extends along a 350m radius and features a 3.06-4.15% lateral, as well as 7.5% of longitudinal, gradient.

For this, Peri's engineers created a formwork solution whereby the side formwork can be hydraulically swivelled inwards when striking as well as allowing the formwork carriage to be hydraulically lowered. In comparison to the conventional, manual striking process, this considerably eases working operations for the site personnel and saves a great deal of time.

Moving to the next concreting section is carried out on rails by means of electrically-operated chain hoists. The entire moving procedure only takes one hour – in spite of the longitudinal gradient. The external formwork is moved from cycle to cycle with the crane.

For the foreman, Östu-Stettin's Martin Fladl, the uncomplicated operability of the Peri formwork carriage is a big advantage. Due to the hydraulic support during shuttering and striking, his formwork crew is able to work quickly, maintaining the tight construction schedule by achieving a five-day cycle. Therefore, two tunnel sections could be sometimes concreted in the space of a week - a rather unusual occurrence in civil engineering.

Peri
Tel: +49 7309 950 0
Web: www.peri.de



Flexible delivery on Turin Metro

Last month, Italian manufacturer Paolo De Nicola announced delivery of three 27t rubber-tired segment carriers to ML3000 Scarl, a JV company consisting of Maire Engineering (Maire Tecnimont Group) and Ghella, for construction of the Piazza Marconi to Lingotto section of Turin's Metro.

The JV partners selected the Paolo De Nicola carriers due to the supplier's level of experience in this sector. Close cooperation between the customer and manufacturer enabled the best solution to be selected, in relation to the unique characteristics of the project.

The result is a highly customised machine that can follow the tunnel's slope and grade, adapting wheel groups to the curved surface with a good pace of diesel-hydraulic translation. The unit has a very compact design resulting from the selected TBM backup, with double cabins for driving in both directions, space for transport of other equipment, and attention to the comfort and safety of workers using specific electronic control devices for easy and secure drive. The low carriers will be employed on the contract 24 hours a day, seven days per week.

Paulo de Nicola
Email: mail@paolodenicola.com

Increased centrifuge capacity

Solids liquids separation plant specialist PSD, from the UK, is adding yet more high-capacity S4-1-G and S5-1-G centrifuges to its rental fleet, which is thought to be the largest rental fleet in Europe.

The centrifuges are controlled by Allen Bradley computerised control systems, with bespoke programming for heavy-duty civil engineering applications. The units are ideally suited to waste mud clean-up for slurry tunnelling, shaft dewatering and run-off water.

The S5-1-G centrifuges are 1100mm in diameter and have a 3300mm long bowl unit, with variable-speed drive powered by a 160kW motor with inverter control. A twin start scroll is driven by a variable speed 55kW motor with inverter control.

The design has been optimised so that the centrifuge is housed within a heavy-duty frame, which allows the centrifuge to be shipped as 20' ISO container units. The powerhouse module houses the PLC, control screen, inverters and control gear for the centrifuge and the variable speed LM100 peristaltic pumps.

The powerhouse module also includes a tank compartment for centrate discharge and a variable speed Metso HM100 pump, with 22kW motor powered from an inverter, for discharge of the centrate from the tank.

PSD
Tel: +44 1772 690 076
Web: www.solidseparation.com

Boomer says farewell to Rocket

The 'Rocket' in Rocket Boomer has come to the end of its journey. As of 01 January this year, only the name 'Boomer' will be used for all Atlas Copco rigs, from the smallest Boomer 104 to the largest Boomer XE3.

The name Boomer has been used as a brand for Atlas Copco's face drilling rigs since the beginning of the 1970s. The name Rocket Boomer was introduced to signify the launch of the COP 1440 high-speed rock drill in 1986.

Today all rock drills delivered on Atlas Copco rigs can be regarded as high-speed drills. Therefore, all newly manufactured rigs will simply carry the name 'Boomer'.

Atlas Copco
Tel: +46 19 670 7119
Web: www.atlascopco.com

Geokon expands north into Canada

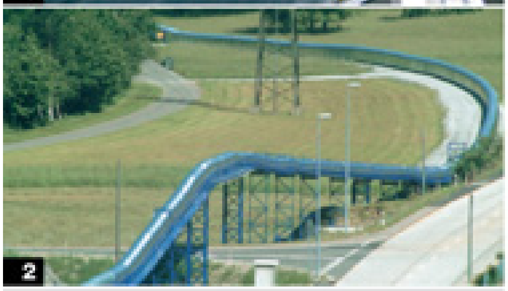
Geokon has recently announced that it has opened a Canadian branch. The company has retained the services of GKM Consultants, of St-Bruno, Quebéc, to assist its efforts in Canada and other countries as the need arises.

GKM Consultants provide integrated monitoring solutions for geotechnical, civil, mining, hydrological and environmental applications, and is founded on solid expertise through qualified and experienced multi-disciplinary staff.

Key personnel at GKM Consultants include, instrumentation system consultant, Martin Dupuis; geotechnical instrumentation consultant, Stéphane-Éric Thivierge; and technical support field specialist, Jean-Marie Bréhé.

For more information on GKM and its highly qualified personnel, visit www.geokon.com/news/gkm.php.

GKM Consultants
Tel: +1 450 441 5444
Web: www.geokon.com



1 Curved belt conveyor in Maurice Lemaire rescue tunnel, France

2 Curved conveyor belt at the Gotthard base tunnel, Faido section, Switzerland

Marti Technics' Sinuous Conveyor Belts to Fit in Curved Tunnels

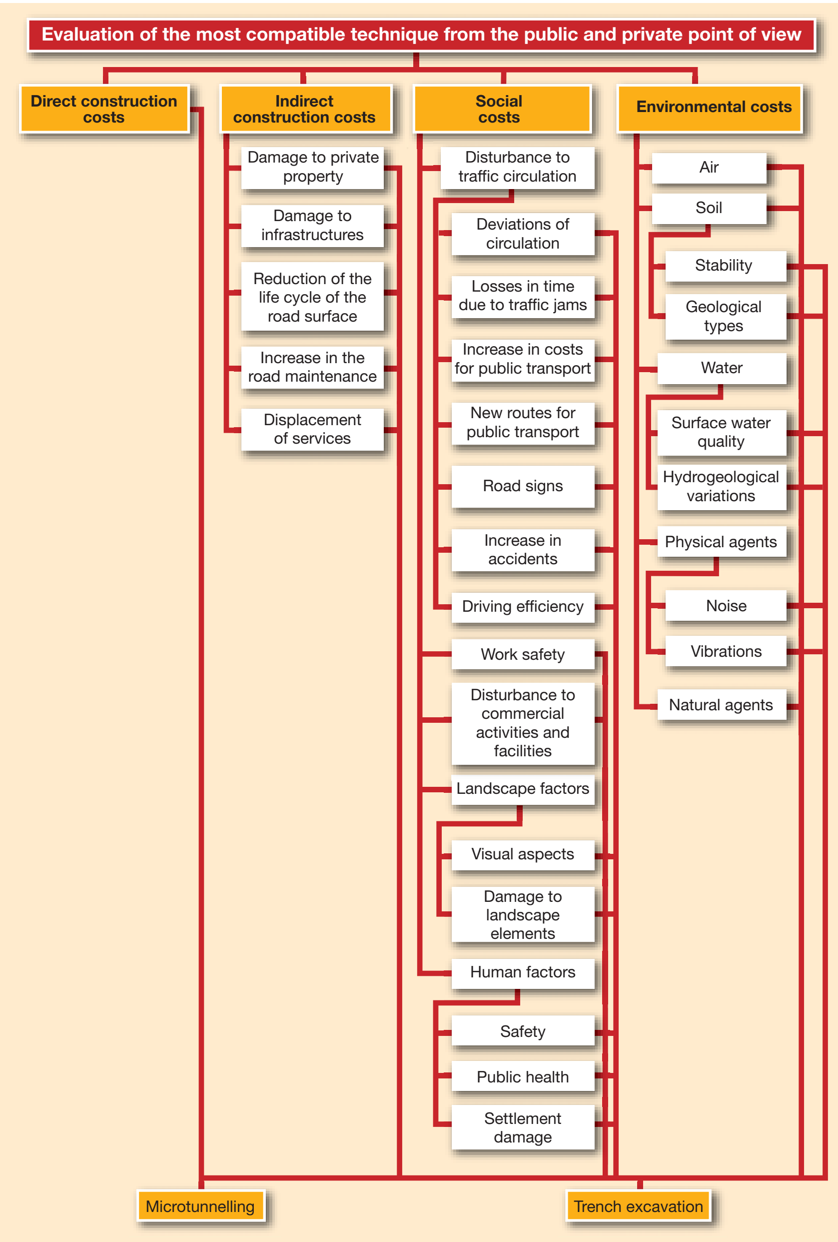
Marti Technics Ltd., the Swiss-based designers, manufacturers and installers of conveyor belts, are able of developing special conveyors suitable for tunnel projects whatever the curves of the alignment.

Tunnel alignments are not specifically straight and one frequent challenge faced by Marti Technics is to propose sinuous conveyor belts, not only inside a tunnel driven with curves but also outside of it. The tensions handled by the belt get even worse as the belt is long. The tail of the belt is fastened to the back-up of the tunnel boring machine while its head is fastened at the portal.

Marti Technics Ltd. Lochackerweg 2 CH-3302 Moosseedorf
Tel. +41 31 858 33 88 www.martitechnik.ch info@martitechnik.ch

Microtunnelling v's open trench

D Peila of DITAG, Dept of Land, Environment & Geoengineering, Politecnico di Torino, Italy, describes a strategy for cost comparisons between two very different methods of excavation



Above: **Fig 1 - Hierarchical structure for a comparison between trench excavation and microtunnelling to install an underground pipe in an urban area**

The use of underground space in urban areas, and in particular the employment of small diameter excavation for installation of service networks, is becoming an increasingly attractive option all around the world.

The aim of this paper is to give a procedure that allows a complete comparison of the different environmental and social aspects involved in the construction of an urban sewer system, with reference to two very different operational methods, i.e. the use of microtunnelling and trench excavation.

The Analytic Hierarchy Process

A comparison between microtunnelling and open-trench excavation can be performed with the use of the Analytic Hierarchy Process (AHP).

The AHP analysis is one of the most widely used multi-criteria techniques available as it can provide extremely useful support in situations where a choice has to be made between several alternatives. Through study of different objectives and criteria, the AHP can assist in providing a quantitative comparison among the considered options.

In this case the AHP methodology was used to compare traditional trench excavation with microtunnelling for an infrastructure installation project in an urban area. The work analysed consists of the installation of a 1.5m diameter pipe along a 500m long street in the centre of Turin in Italy.

In reality, the pipe was installed at an average depth of 2m by excavating a trench from surface but this paper clearly shows that the use of microtunnelling would have been a much better, and far less disruptive solution.

The analysis was undertaken after studying the results of a questionnaire that had been given to the people in the area surrounding the job site. This was obviously to asses, and focus on, the most relevant social impacts the project would have on the local population.

The specific goal of the analysis was to define which excavation technique was

Goal: Evaluation of the most compatible excavation technique from the public and private point of view	Direct construction costs	Indirect construction costs	Social costs	Environmental costs
Direct construction costs	1	1/3	1/3	2
Indirect construction costs	3	1	1	5
Social costs	3	1	1	5
Environmental costs	1/2	1/5	1/5	1

Above: **Fig 2 - Comparison matrix used in the AHP analysis. It can be seen that the indirect construction costs and the social costs were considered very important and therefore they were given high weights**

most compatible, from the point of view of the public and private actors affected by, or involved in, the construction.

With reference to the basic principles of the AHP, the first step of the analysis was to define the hierarchical structure which would correctly represent the problem (figure 1) and the following general cost criteria, which together would give the "global cost" of the underground construction, the cost criteria are:
- direct construction costs
- indirect construction costs
- social costs
- environmental costs

Analysis of the general criteria

Direct construction costs - The direct construction costs involve the installation of the pipe and consist of the total economic resources involved in the "physical" work and in the recovering of the site at the end of the works.

These costs, with reference to the example being studied, are higher for microtunnelling than for the open trench excavation. It is necessary though to remember that the presence of groundwater, buildings or very sensitive infrastructure can swing this assumption in favour of microtunnelling.

Indirect construction costs - The indirect costs are the expenses for materials, machinery and works not directly related to the construction phase.

The subsequent costs were taken into account in the analysis:
- damage to private property
- damage to other infrastructures
- reduction in the life cycle of the road surface
- increase in road maintenance
- relocation of services that interfere with the works

They all contribute in various ways in determining the final construction cost, and this contribution can be evaluated using the Analytic Hierarchy Process. In the studied example the highest cost is attributed to the relocation of existing infrastructure (clean water, telephone networks, etc).

Comparing the two alternatives, with reference to the indirect construction costs, the surface excavation was considered to be the worst since microtunnelling involves a limited construction site area, reduces the damage to road surfaces, to private property and to the existing services. Importantly, the use of microtunnelling also minimises the relocation of the already existing underground infrastructures, which is limited to the shaft area instead of to the whole pipe length.

Social costs

The social costs are the costs incurred by society during the construction of the project.

They are caused by the interferences between the construction site and their affect on economic activities of the area.

The following costs therefore were taken into account:
- problems of traffic circulation
- safety aspects of the works site
- disturbance to commercial and recreational activities in the area
- landscape factors
- human factors

Considering the complexity of the topics involved, it is necessary to further divide them. The criteria related to costs for problems related to road circulation were divided into:
- measures for the diversion of traffic circulation
- loss of time due to an increase in circulation and traffic jams
- choice of new routes for public transport
- installation of new road signs
- higher number of road accidents
- driving efficiency
- increase in the costs of public and private transport

The increase in the costs for public and private transport, the driving efficiency and the increased number of road accidents were considered to be the most important in the studied example.

If these criteria are taken into account, the open trench excavation is proved considerably more damaging to society than microtunnelling.

The criteria related to work safety is obviously linked to the costs borne by the contractors and by society for the safety of the workers in the construction site area. In the analysis, these costs were considered as being directly proportional to the surface area of the construction site. The bigger the area, the higher the exposure of the workers to risks. Therefore, as the construction site is larger for trench excavation than for microtunnelling the costs for safety were considered higher for the former solution.

The criteria related to disturbances created to commercial and recreational activities is directly connected to the physical barriers that result from the construction site on the fore-mentioned shops and facilities. Generally speaking, it is possible to say that the disturbance is higher for traditional excavation, especially if the roads are closed to both vehicular and pedestrian access and this was clearly seen in the results of the questionnaire.

The criterion related to landscape factors has to be evaluated considering the negative impact generated by this type of construction site on the "urban and territorial values" of the area. In generic terms, the transformation of the urban landscape due to the construction site is reversible and when the works are over it is possible to restore the previous conditions or even improve them. In the analysis, the two options are considered equal.

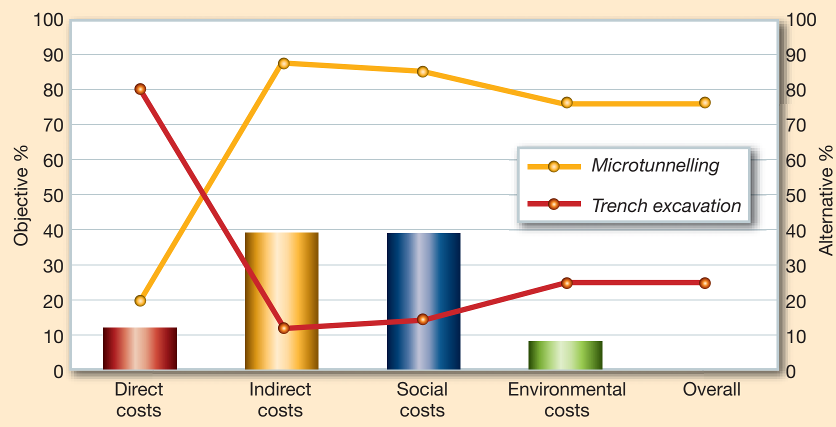
The criterion related to human factors is associated to negative impacts caused by the construction site on the inhabitants of the surrounding area. In the analysis, this criterion was divided into:
- aspects related to public safety
- aspects related to public health
- aspects related to settlement damage

These elements involve possible disturbances to the inhabitants of the area due to the construction site (noise, dust, vibration) and again this aspect was highlighted in the answers of the questionnaire.

The impacts of the construction site for the installation of a sewer pipe system are transitory and therefore stop when the works are over. Ironically they do, however, cause the highest number of complaints from the population. In the

Table 1 Priority list of the general criteria

Direct construction costs	13.7%
Indirect construction costs	39.4%
Social costs	39.4%
Environmental costs	7.5%



Above: Fig 3 - Performance graph which visualises the priorities of the final alternatives with reference to the general criteria

analysis, the project's effect on public safety and health were considered to prevail over the effect on structural quality of the houses, which, generally speaking, are not particularly troubled by this kind of excavation

It is intuitive then, that the trench excavation is worse than microtunnelling as it tends to create a higher impact in terms of dust emissions, noise and vibrations in the surrounding area.

Environmental costs

Environmental costs are used to quantify the permanent negative effects of the operations due to the deterioration of environmental components. In the analysis, the factor was divided into five criteria (air, soil, water, physical agents, natural agents) and each of them was given the same weighting.

In order to improve the analysis, some of the five sub-criteria were further divided into simpler elements. For example, with reference to air, trench excavation has been considered to have more serious negative effect than microtunnelling because of the greater consumption of fuel, and consequent toxic emissions into the atmosphere caused by machine exhaust.

With reference to environmental costs microtunnelling is preferable to trench excavation

Comparing the two alternatives

In order to develop the comparison between the final alternatives, specific weights must be given to each general cost. With reference to the AHP approach, a comparison matrix was constructed (figure 2) and the related priority list is represented in Table 1.

It can be observed that in this study some aspects that are usually underestimated by decision makers, such as indirect construction costs and social costs, are considered and high weights given to them.

This choice is arbitrary and is closely linked to the decision making process.

In the studied example, the evaluation was made whilst trying to highlight society's point of view and therefore the social and environmental costs take on a greater importance.

Using the priority list of the general criteria, with the AHP model, it is possible to compare the two alternatives. The results give trench excavation a final score of 23%, while microtunnelling has a final score of 77%. This means that microtunnelling is considerably better when taking into account the point of view of society and the environment and not only limiting the analysis to direct costs. In fact, ONLY if the analysis is performed maximising the weight of direct costs, does open trench excavation become preferable to microtunnelling.

The Performance graph (figure 3) visualises the priorities of the final alternatives as regards to the general criteria.

Conclusions

The comparison of trench excavation and microtunnelling carried out in this analysis shows that, if indirect construction costs and social and environmental costs are considered with appropriate weights, microtunnelling is preferable to traditional trench excavation. This is also true for easy operations, such as the installation of a sewer in a road of medium importance (that can be closed to traffic) as was the case which was analysed in this work.

Obviously, the analysis requires the decision making process to give adequate weights to the various costs which together form the global cost of the work and to use computational methods which will allow an easy comparison between the various possible construction alternatives.

The analytical tools (AHP) that were used in this paper are suitable for a complex and multi-dimensional analysis, even though it is necessary to improve the definition of the costs related to the social or environmental aspects, such as the costs borne by society in the case of traffic jams. T&T

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Desiree Willis, of The Robbins Company, describes the trenchless technology adopted to minimise surface disruption and environmental impacts during the construction of the Milford Haven Gas Connection Project, in Wales

Above: A Robbins SBU-M utilises disc cutters to bore hard rock of over 170MPa

Microtunnelling for Milford Haven

The Milford Haven Gas Connection Project is one of the most extensive infrastructure projects recently constructed in the UK. Stretching over 300km across South Wales, the pipeline traverses townships, major rivers, and roads, as well as environmentally sensitive habitat.

In order to minimise surface disturbances, over 110 crossings using multiple types of trenchless technology were developed. The crossings, which range from soil to hard rock, are anywhere from 20m to 330m in length and utilised technology such as microtunnelling systems (MTBMs) and auger boring with Small Boring Units (SBUs). Choosing a successful methodology depends on factors including geology, line and grade, and crossing length.

Above: The 20 hard rock crossings on Phase II of the Milford Haven Gas Connection Project utilised three Robbins SBU-As

Project overview

The Milford Haven Pipeline supports the UK's increasing requirements for imported natural gas. Liquified Natural Gas (LNG) is imported from international sources to two terminals located in Milford Haven. Tankers offload the LNG, where it is then converted back to its gaseous form at the terminals before entering the pipeline. The pipeline will eventually transport up to 20% of the UK's natural gas for owner National Grid.

Constructed in two phases, work began on the pipeline in early 2006. Phase I involved a 120km long stretch from the towns of Milford Haven to Aberdulais. Phase II of the project extended the pipeline another 185km from Felindre to Tirley in Gloucestershire. A total of 57 trenchless crossings were excavated during Phase II of the project. Both phases were finished in November 2007.

Utilising trenchless technology was one way that general contractor NACAP/Land & Marine worked to maintain environmentally sensitive areas. Tunnelling under features such as rivers and woodland in the Brecon Beacons National Park minimised disturbance to the indigenous flora and fauna in the region. Vibration and movement were closely monitored, and the working area restricted at several points to minimise disruption of the surrounding landscape.

Methodology of crossing

The majority of the pipeline and its crossings were excavated using cut and cover, with trenchless methods reserved for ecologically valuable or heavily trafficked areas. While an above ground pipeline was considered, it was ultimately decided against because of the method's visual impact on the landscape and need for frequent maintenance.

In cut and cover sections, 12m-18m lengths of high-grade steel pipe (1.2m o.d.) were welded together to form strings. A trench was then excavated and the pipeline lifted in before the trench was filled. Land drains were then installed in order to re-instate pre-existing land drainage patterns.

Crossings in ecological areas located in hard rock or mixed ground with relatively little water used a specialised type of technology. Local contractor B & W

Above: A 1.2m Robbins SBU-M excavates a river crossing in siltstone between 70 and 200MPa

Left: An SBU-M is lowered into a concrete-lined launch shaft to bore a line- and grade-sensitive river crossing

Tunnelling excavated 24 hard rock crossings ranging from 20m to 80m in length during Phase II of the project. Five Robbins hard rock Small Boring Units (SBUs), excavated the line- and grade-sensitive crossings underneath major rivers and roadways.

A total of 20 crossings utilised three 1.2m diameter SBU-A machines, a type of hard rock boring attachment. The technology utilises disc cutters to excavate mixed ground or hard rock, from 25 to over 170MPa, in conjunction with a full-face auger. The machine is welded to the lead casing while an Auger Boring Machine (ABM) provides torque and forward thrust to the cutting head. The machine is typically used on drives less than 100m in length for diameters ranging from 600mm to 1.8m.

The Milford Haven crossings were located in siltstone rock with a UCS of ranging from 70 to 200MPa, often interbedded with clay and gravel. These crossings did not require deep shafts, but instead used shallow 24m long x 3m wide launch pits.

Four of the longest hard rock crossings underneath rivers required deep shafts and were line-and grade-sensitive with a contractual 50mm tolerance. B & W Tunnelling opted to use a relatively new technology to accomplish this task - two 1.2m diameter Robbins SBUs (SBU-Ms).

"We needed an increased degree of accuracy given the shaft depths and the line and grade of the crossings, so we felt the most confident using the SBU-M," says Steve Williams, managing director of B & W Tunnelling. SBU-M excavation went extremely well for the duration of the project, with average advance rates of 1.5m to 2m per hour and no disc cutter changes.

The Motorised SBU is a manned-entry, hard rock boring machine used for longer bores (150m+) and for line and grade critical crossings. It is used in conjunction with a standard Auger Boring Machine (ABM) and is welded to the lead casing in the same fashion as SBU-As. While both SBU-As and SBU-Ms are used with ABMs, the SBU-M has a small invert auger for spoil removal rather than a full-face auger.

The cutterhead is supported by a heavy-duty bearing housing assembly and driven by either a hydraulic motor or a water-cooled variable-speed electric motor. The motor provides torque to the drive train and contains a torque limiter to protect the drive train in case of cutterhead jams in fractured or broken ground conditions.

The SBU-M can be steered from an operator's console inside the machine's rear shield. Hydraulic articulation cylinders and manually-adjustable stabiliser shoes allow for continuous control of line and grade, while a laser target system provides measurement of boring accuracy.

Each SBU-M crossing on the Milford Haven Gas Connection Project required the use of 10m to 30m deep launch and recovery shafts. The 10.5m diameter shafts were lined with concrete-bolted segmental rings and were used to install the pipeline after the crossing had been excavated. Sacrificial steel casing (1.2m o.d.) was used to provide the necessary forward thrust to the cutting face from the ABM. The pipe was later removed and a semi-automatic welding bug was used to install the final pipeline. The process allowed for extensive weld testing of each pipe length, which was performed along the entire pipeline.

Microtunnelling

Some crossings, particularly long crossings underneath major rivers, required the use of microtunnelling technology. For Phase II there were 11 MTBM crossings in mixed ground and hard rock. "We based the decision to use microtunnelling on the ground conditions and risk of water ingress revealed during geotechnical investigations of the site areas," explained Bas Grit of Land & Marine. Site investigations performed by the NACAP/ Land & Marine JV included trial pits and auger/rotary bore holes.

The MTBM crossings ranged from 30m to 330m in length and required the construction of large shafts 7.5m in diameter and more than 30m deep. The shafts were lined with concrete segments, and were constructed by caisson sinking in soft ground and underpinning in the harder ground.

Once each MTBM crossing was complete, 6m lengths of 1.2m o.d. steel pipe were lowered into the shaft. Semi-automatic welding bugs, as in the hard rock crossings, were then used, while a winch in the opposite shaft drew the newly-welded pipe lengths through the tunnel until the crossing was complete.

In November 2007, Energy Minister Malcolm Wicks MP officially opened the 316km pipeline and all ancillary structures. Successful installation of the pipeline required hydrostatic testing, before being dried and filled with LNG. Several above-ground structures, including a compressor station built near Felindre, keep the pipeline operating at peak capacity.

The station operates at a pressure of 94 bar to allow for optimal flow rates throughout the year. T&T

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...for projects July to December 2007

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PORR, BÖGL

cable car

crane car with basket

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rail running mixers 12/16 m³

review 2007

- Tunnel Fritzens - Austria
- La Cabrera - Spain
- Srisailam - India
- St. Gotthard Tunnel - Switzerland
- Dez-Ghomroud Water Transition Tunnel - Iran
- Spillvatten Tunnel - Sweden
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- Tunnel Wienerwald - Austria
- OLMOS Proyecto Trasvase - Peru
- Proyecto Hidroelectryco Pinalito - Dom. Rep.
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Gautrain, South Africa
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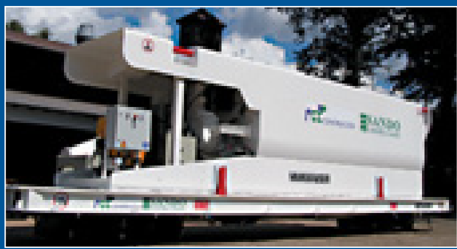
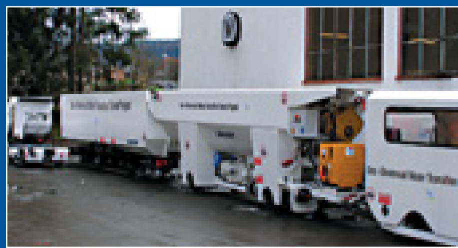
mortar cars, men boxes



La Cabrera, Spain
FCC, SANDO

mortar cars, flat cars



Dez-Ghomroud Water Transition Tunnel, Iran
SABIR Co.

muck cars, mortar cars, segment cars, menrider

Spillvatten Tunnel, Sweden
Beton- und Monierbau

train loading system, muck cars, shotcrete cars, flat cars

Srisailam Tunnel, India
JAIPRAKASH Ltd.

men box, silo box, crane car, segment car, flat car

Project Hobson bay Tunnel, Australia
McCONNEL Dowell Ltd.

floorshaft cars, segment cars, flat cars

Mostovik, Russia
NPO Mostovik

mortar cars

St. Gotthard Tunnel, Switzerland
Consorzio TAT

remote control cars, men boxes, remixers KBM12, rota cars

Reno Crossing, Italy
I.C.O.P.

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Tunnel Fritzens, Austria
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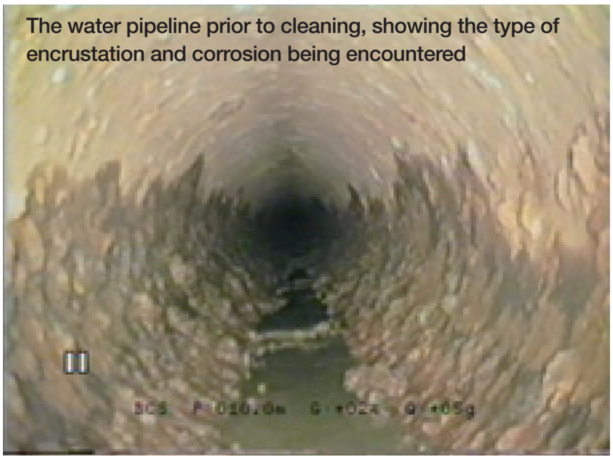
View down one of the access manholes utilised during the lining works at Kilroot



The water pipeline prior to cleaning, showing the type of encrustation and corrosion being encountered

A UV light cured liner system was successfully employed to aide the renovation of pipelines for the Kilroot Power Station, one of Northern Ireland's biggest energy sources. Technical journalist, Ian Clarke, describes the operations undertaken

UV lining aides Kilroot renovation

Kilroot Power Station, some 12 miles northeast of Belfast, is an oil and coal burning power station that produces around one third of Northern Ireland's electricity. Being such an important power generator, the facility must always be kept at its best efficiency and operational performance.

As part of ongoing maintenance work to ensure this, a CCTV survey of the existing 420mm diameter, steel seawater pipelines, which have been in use for over 30 years, was undertaken. The survey showed signs of severe encrustation and corrosion, with up to 30% of the pipe cross section being obstructed in places. Corrosion had also removed a length of some 7m in the invert of one pipe and there were also numerous small holes throughout the length of the pipes, which allowed the ingress of water in the form of jets and seepage.

The power station owners, Applied Energy Services (AES) Kilroot Ltd, and the Kilroot Power Station maintenance department management decided the best option to aide the pipeline's renovation was relining due to parts of the pipeline running beneath surface obstacles. One of the pipelines, of 27m length and 3.5m depth, ran under a rail track. The other 6m long, 3m deep section to be lined ran under the main Power Station buildings.

The right lining option

Dyno-Rod (NI), based in Belfast, was approached by AES to complete the lining work. After careful consideration of the lining options, taking into account the site conditions, ultimate operational requirements and the time scale involved, it was decided that lining would be completed using a UV light cured liner system. The project brief from KPS stated that the liner should be capable of withstanding temperatures of 40° to 90°C.

With this in mind it was decided to install the liners using a Prokasro-manufactured UV lining system in association with Saertex liners. This was because Saertex UV liners are factory produced and therefore quality can be guaranteed, both from the factory and the onsite process.

The use of UV curing also meant that, should unforeseen circumstances arise, it would not bring with it potential problems that can occur using hot water or ambient cure resin systems, which might cure prematurely in the pipe in such circumstances. In the UK, the Prokasro UV cure lining equipment and the Saertex liners are supported by engineering consultant CJ Kelly Associates Ltd, of Peterborough, which has some nine years experience covering all forms of lining technology in the pipeline renovation sector.

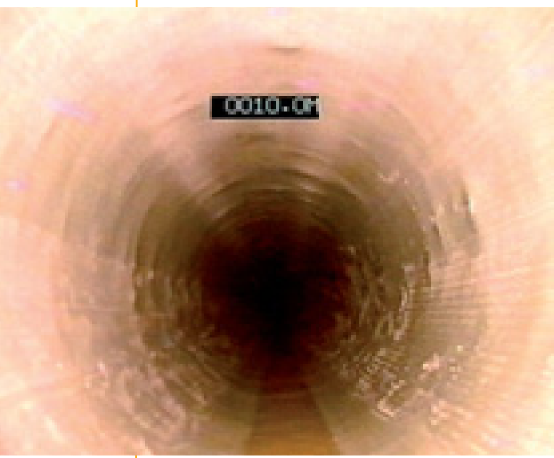
Above: Lining works underway

Installation works

During a two-week preparation programme on the pipes being renovated, prior to relining, weather conditions were good, as were the ground conditions, with little or no infiltration of groundwater into the pipes or manholes. The initial work to prepare the pipe for lining comprised removing obstructions, encrustations and corrosion using proprietary methods.

Some initially unforeseen work was however added to the workload, which included insertion of some local epoxy patch liners to stop ingress of water through the pipes' deteriorated walls to

Above: The control console onboard the UV lining truck



Above: The water pipe after lining

enable full lining to take place. Other water ingress problems also occurred during the early stages of the lining works and this subsequently led to further works being added to the contract to seal the manholes with polyurethane resins to ensure the system was sealed against future inflows prior to the lining installations.

As part of the lining preparations, some 1.5m^3 of benching and steel pipe work also had to be cut and removed under confined space working conditions to enable the reline to take place. The benching and manhole works were made good after the reline operation was completed.

Despite good weather for the preparation works, on commencing the lining work in early October 2007 weather conditions were very bad with some 30mm of rain falling in the first three hours on site. This meant that water poured in through the walls of the manholes and the 420mm diameter blow down pipelines. Work was therefore abandoned that day.

The next day water was still flowing into the system even though there had been no further rain, and later in the day KPS informed the contractor that a 150mm diameter water main had burst on the site, which was likely to be contributing significantly to the water ingress problem, so again work was stopped.

It was then decided to seal the pipes and manholes with additional patch liners in the pipes and resin sealing at the manholes. Once this was competed any further water ingress into the system was manageable using 50mm diameter sludge pumps.

For the power station application it was decided that a Saertex liner of 6mm wall thickness would be suitable for the operational temperature requirement of the pipeline and two individual lengths of 420mm diameter liner for the 27m long and 65m long installations were prepared and delivered separately.

Preparation works started on 28 September 2007, with installation of the first liner on 03 October. All liner installations were completed by 06 October including the refitting of the 420mm diameter, 45° bends into manhole and re-benching work.

UV lining

The UV lining system utilised by Dyno-Rod at the Kilroot Power Station is installed using a very specific technique. First the pipe to be lined is fully prepared and cleaned. A protective foil is then run through the pipe. This prevents damage to the liner fabric as it is winched through the host pipe. The Saertex factory-prepared and impregnated liner is then pulled through the host pipe over the whole lining length using a winch cable. During manufacture of the liner a small pulling rope is inserted into it. This is used during the pre-curing set up to pull the Prokasro UV light train into position inside the uncured liner from the front end.

The rear end of the UV light train is connected to the control vehicle via a cable, which not only provides the control connections but also the motive power to move the light train through the liner during the curing process. The end seals are then made good to ensure the system is airtight.

The liner is then inflated with compressed air to ensure a tight fit against the inner wall of the host pipe whilst the cure takes place.

Once all is in place, the UV lamps are turned on and allowed to come up to temperature, so starting the cure. The UV light train is then pulled through the inflated liner using the control cable.

The speed of advance of the light train along the liner determines the exposure time of the UV sensitive resin to the light source and so the curing time. All the light train operations and speed of advance are controlled from a specially designed control cabin within the support truck of the system and can be operated by one person.

Once the light train has passed along the liner length and the curing has been done the UV lamps are turned off and allowed to cool. The liner ends are then opened and the UV train removed.

A protective inner foil in the Saertex liner, used in the curing process to protect the liner during the light train pull through, is then removed. The liner is now ready for use. It is at this stage that any lateral connections are remade using a remote controlled robot, which can also be controlled from the support truck. The newly lined pipe is ready to be re-commissioned into active service.

Commenting on the project Radenko Danilovic, Dyno-Rod NI's business development manager said: "At first the project looked reasonably straight-forward with just two linings needing to be done. The Power Station had been shut down for approximately three weeks and was under going a major maintenance overhaul, so the cooling water pipes were only available to work on between 17 September and 06 October. The Station was due to start the firing up process the following week with all contractors permits to work being cancelled on 07 October. As a result of this, other contractors needed access to the area in which we were working. This hindered our work method and the available timescale. Ultimately, this other work and the extra sealing works that had to be completed before lining could take place meant that, to meet our goal, our crews had to work longer on a daily basis, as well as working an extra two days. But we managed it very well."

For CJ Kelly Associates, John Kelly, managing director commented: "Many people in the water and drainage industry seem to think that lining is something only for the foul and storm water sectors. The Kilroot Power Station project has shown just how useful the right liner can be in more industrialised situations.

The increase in interest for UV lining technology, particularly over the past year, has been very encouraging and we feel that 2007 could mark a major turning point in the development of this technology within the UK renovation sector.

UV lining offers not only quick, easy installations but also improved environmental standards, with reduced styrene emissions, and even less disruption to traffic in the wider world as well as in ongoing operations in situations such as those found at Kilroot." T&T

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20-21 MARCH
China Tunnel Summit 2008 Shanghai, China
Thia two-day seminar includes presentations by a number of eminent speakers from the international tunnelling community. Subjects covered include advanced design concepts, new technologies, operation and management, current research and case histories. Contact: Merisis Consulting; email: boris.ziong@merisis-asia.com

20-22 MARCH
International Symposium on Underground Freight Arlington Texas, USA
Organised by the University of Texas and the Center for Underground Infrastructure Research and Education (CUIRE). Contact: University of Texas; tel: +1 817 272 0507; email: najafi@uta.edu; web: www.cuire.org

10-12 APRIL
IS-Shanghai 2008 Shanghai, China
The 6th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, is organised by Tongji University under the auspices of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE). For more on this symposium on booming China; Contact: www.tc28-shanghai.org

22-24 APRIL
5th International Symposium on Sprayed Concrete - Wet Mix Lillehammer, Norway
Organised by the Norwegian Concrete Association, main themes will be design, construction and durability of wet-mix sprayed concrete. Results from the Hanekleiv investigations, will also be presented. Contact: Email: info@sprayedconcrete.no; Web: www.sprayedconcrete.no

4-7 MAY
13th Australian Tunnelling Conference Melbourne, Australia
"Engineering in a changing environment" is the topic of the 2008 Australasian Tunnelling Society conference. The present buoyant conditions in civil infrastructure and mining Australia and New Zealand promise a great programme. Contact: AusIMM; email: dedwards@ausimm.com.au; web: www.atstunnelling conference2008.com

20-22 MAY
Intertunnel 2008 Turin, Italy
This bi-annual international exhibition will focus on major projects in Italy. The show promises to be an excellent networking environment, bringing together experience from tunnelling projects in many countries. Contact: Olivia Griscelli, exhibition director: email: intertunnel@mackbrooks.com; web: www.intertunnel.com

3-6 JUNE
International No-Dig 2008 Moscow, Russia
Hosted by the International Society for Trenchless Technology and co-hosted with the Russian Society for Trenchless Technology, this will be the first ISTT event to be held in Russia. Contact: ISTT; Tel: +44 20 7259 6755; email: info@istt.co.uk; Web: www.istt.com

7-11 JUNE
North American Tunneling Conference San Francisco, USA
The 2008 NAT Conference will be held at the Hyatt Regency, San Francisco. Abstract deadline is November 2007. Conference programme and registration details TBC. Contact: Society for Mining, Metallurgy and Exploration (SME); www.smenet.org

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

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 telecommunications in an underground environment (tunnels, metros, mines, etc). Contact: web: www.icwcuca.ca

17-18 SEPTEMBER
IUT'08 5th International Underground and Tunnel Fair, Sargans, Switzerland
Time to go underground again, at what is becoming one of the calender's premium events. Held in the unique setting of Switzerland's Hagerbach Gallery. On 19 September, technical tours will take place. Contact: 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 to be undertaken in the near future in India, there is much scope for agencies within as well as outside the country, to demonstrate their capabilities. 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, has become a popular addition to the event callendar. Contact: Messe Berlin; Web: www.innotrans.com

BRITISH TUNNELLING SOCIETY

20 FEB: **"Drill & Blast Tunnelling - Bristol City Centre Flood Alleviation Phase II"**
Joint meeting with MinSouth. Presented by Richard Soloman, Mark Thomas and Damian McGirr. 6pm start, at the ICE, Westminster, London.

20 MAR: **"Tunnelling Works for the Bosphorus Crossing - Istanbul, Turkey"**
Presented by various members of the project team. NB: This meeting will start at 6.30pm.

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

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

23-28 MAY 2009
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

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', Wilmington House, Maidstone Road, Sidcup, Kent DA14 5HZ, United Kingdom.
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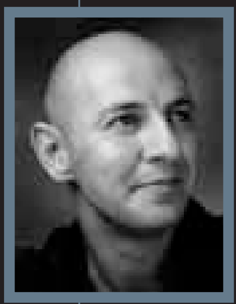
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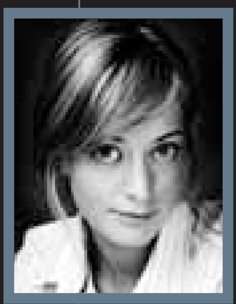
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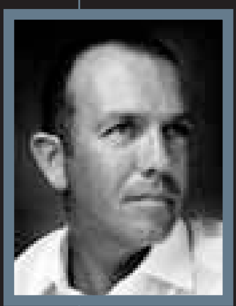
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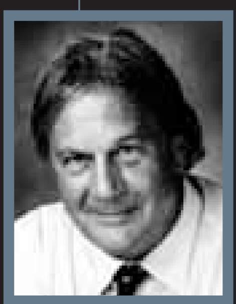
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