

APRIL 2009

tunnels & tunnelling INTERNATIONAL



FOCUS ON EUROPE

Site reports from tunnel projects in Austria, Italy, Spain, and Hungary

CAST IN-SITU LINING

Cost efficiency is the key to this widespread method of concrete placement

BREAKTHROUGH SOLUTIONS



Earth Pressure Balance
Slurry Pressure Balance
Hard Rock
Pipe - Jacking
Rolling Stock

LOVAT

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

Contents

FRONT COVER:
A finished stretch of the TBM bored Oliola water tunnel in Spain created to alleviate the recent drought that has ravaged the north Eastern Catalonia region (p25).

WEB ADDRESS
www.tunnelsonline.info

CONVERSIONS
US\$1.00
0.76
£0.68



47

Concrete batching plants are a typical site on many tunnels

5 COMMENT

6 WORLD NEWS

12 BUSINESS & FINANCE

FOCUS ON EUROPE

16 BRIDGE OVER THE INVERT

The Achrain Tunnel - a bridge underground
To allow continuous NATM construction with a fast invert closure a bridge was built over the invert to allow access to the face

21 CONTAMINANT CONTROL

Asbestos isolation
When asbestos stopped tunnelling in Italy, a novel method was created to store the muck in an underground repository

25 SPANISH SYNTHETICS

Spain's synthetic reinforcement
Macrosynthetic fibres are becoming more common as reinforcement in concrete segments. *T&T* looks at a Spanish example

28 HUNGARY'S CAPITAL METRO

Building new links in Budapest
Construction of the first phase of Budapest Metro's Line 4 is now in full swing, here station construction is reviewed

33 PRODUCTS & SERVICES

35 BRITISH TUNNELLING SOCIETY

Mine stabilisation below Hatfield
The February meeting of the BTS and MinSouth saw a presentation on the works to stabilise old mine workings in the UK

41 RISK ANALYSIS

Probability and risk management
T&T looks at a novel method of risk assessment and management using computerised probability methods

CAST IN-SITU LINING

47 CAST IN-SITU

Concrete casting
T&T reviews recent trends in the field of cast in-situ lining and finds speed of works and measures of economy still prevalent

51 CLASSIFIED ADVERTISEMENTS

53 DATES & EVENTS



7

Shanghai's Line 7 metro receives some finishing touches



INDIA: LONG DISTANCE TUNNELLING BENEATH A NATURE RESERVE.

With a length of 1,290km, the Krishna is one of India's longest rivers. It is located in the south of the country and has two large dams along its course. In the vicinity of the Srisailem Dam, an 18.8km-long underground tunnel is to be driven with the purpose of redirecting excess water from the dam's reservoir during the monsoon season into areas which are plagued by drought. The Herrenknecht Double Shield S-370 (Ø 7.96m) is being deployed for this demanding irrigation project.

The machine with a driving power of 2,800kW will drill at a depth of down to 550 meters below the "Rajiv Gandhi" nature reserve known for its tiger population. The Veligonda project is being supervised on site by the Herrenknecht subsidiary "Underground Technology Services". UTS is not only responsible for the assembly and operation of the TBM, but also for the installation, control and maintenance of the segmental lining production plant and for training the customer's personnel.

On August 19, 2008 the Prime Minister of Andhra Pradesh, Dr. Y. S. Rajasekhara Reddy, was present on the construction site to launch tunnelling operations which are to be completed by the end of 2011.

KURNOOL | INDIA

PROJECT DATA

S-370, Double Shield
Diameter: 7,960mm
Driving power: 2,800kW
Tunnel length: 18,800m
Geology: quartzite, slate, phyllite

CONTRACTOR

Coastal Projects
Pvt. Ltd.,
Nuziveedu Seeds Ltd.



Cash in a crisis...

As if to shadow the *T&T* comment from October last year, where we tried to offer a glimmer of optimism for our sector in the face of a world recession, the news this month is full of large scale tunnelling projects that appear to completely buck the current trend for economic depression.

In Mexico City we see plans for a 62km long, 7m diameter, multiple TBM bored water tunnel, as Shanghai puts finishing touches to its 9km long Line 7 underground section whilst announcing that by 2010 another six lines will be added to its existing five. In the UK Bechtel gets the go ahead as delivery partner for London's Crossrail mega-project, Europe's largest planned infrastructure project, as in India, the 14 TBMs on the Delhi Metro appear to be heading to hit the tight deadline of tunnel completion by December. Hong Kong is reclaiming its crown as the tunnelling place to be with a raft of projects in the planning, whilst Scandinavia offers stiff competition from projects such as the Copenhagen Metro and the planned 18.5km long road and rail link between Germany and Denmark. These are but a few examples, the list in reality goes on and on.

The recession has brought one real glimmer of light to the tunnelling industry. It has started to put underground infrastructure on the client radar far more than previously. Who would have thought five years

ago the London Mayor would be singing the praises of tunnels in his newspaper column, read by hundreds of thousands? We have to hope that this isn't just political lip service, promising employment for thousands and infrastructure legacies to last. It is vital that governments put their money where their mouths are and stump up the funding through public spending, or confidently enter delivery methods in partnership with the private sector that will allow financing to be secured.

We can provide the skills to build these structures, now they must do their bit, and provide the skills to deliver the financing.

On a completely different and slightly sad note, we must bid farewell this month to *T&T* Deputy Editor Amanda, who's been with the magazine through thick and thin for nearly 10 years now. It's been great fun, and Amanda's also played a very big part in the development of *T&T* over the decade (and put up with me threatening to throw my computer out of the window on many occasion). And for that I thank her sincerely. But don't worry, she's still staying with the industry and will be heading up the North American *T&T* full time.

We wish her all the very best, and I'm sure she'll thrive in her new editorship. Good luck Amanda!

Tris Thomas



COMPANIES IN THIS ISSUE

3G	16	Concrete Pumps	49	J F Shea	7	Porr	8, 38
A&K Geotechnical Engineering	21	Condor Johnson	12	Jacobs Engineering	7	Procon	7
Acciona	25	Costain	8	Jäger Bau	8, 16	Putzmeister	47, 49
Aecom	7	Cowi	12, 14	JCM	12	Renner Colony	14
Aecon	7	Doka	50	Knight Piesold	8	RJM Ground Solutions	35, 36
Aedas Group	7	Dragados	7, 49	Laing O'Rourke Holdings	7	Robbins	6, 10, 25
Aggregate Industries	14	D-Tec	33	LCR	7	Rockworks	37
Allentown	49	Elasto-Plastic Concrete	26	Lombardo Construcciones	6	Schiavone	7
Alpine Bau	16	Elkem Materials	50	Lovat	6, 8	Schönherr Landskab	14
ANAS	21	Eskom Holdings	8	Mace	35	Scott Wilson Railways	7
Arup	7, 12, 14,	Euroform	14	Marti Tunnelbau	8	Seli	6, 7
Atkins	7, 12	Faber Maunsell	14	Max Bögl	8, 38	SEM Concrete Placer Pumps	49
Balfour Beatty Management	7	FCC	49	McNally	7	Sigma Engineering International	14
BAM Ritchies	35, 36	Femern Baelit A/S	14	Mitsubishi Heavy Industries	10	Sika	14
Bamtonnelstroy	6	Fortius	50	Modern Continental Construction	14	Sireg	50
Barath Earth Movers	12	Frontier Kemper	7, 12	Mott MacDonald	7	SN Power	10
BDP	7	Gannet Flemming	14	MTR	12	Soma	10
Bechtel	7, 14	Grontmij/BGS	14	Mühlhäuser	47	SoundTransit	12
Bekaert	50	Grontmij/Carl Bro	14	Network Rail	37	SSP Bau-Consult	41
Beton- und Monierbau	16	Halcrow	7	NFM Technologies	12	Statkraft	10, 14
Bilfinger Berger	7	Herrenknecht	6, 8, 14	Nichols Group	7	Sund & Baelit A/S	14
Bung	14	HPDI	12	Norfund	10	Systra	7
Capita Symonds	7, 14	HTG Ingenieurburo fur Bauwesen	14	Northcroft	7	TEC	14
Carso Infraestructura y Construcción	6	Hyder Consulting	7, 35	Obayashi	7	Tek.Sp.Ed	49
Caterpillar	8, 49	Ibérica de Bombeos Especiales	49	Obermeyer	14	Thames Water	8
CEC	10	iC	16	Oriental Consultants	14	Traylor	12
Ceresola	49, 50	IFT Fasertechnik	50	Ostu/Stettin	8	Tube Lines	7
CH2M Hill	7	IGT Ziviltechniker Gesellschaft	16	Parsons Brinckerhoff	7, 14	Wayss & Freytag	8, 38
CMC	14	Impregilo	8	Perco Engineering Services	33	Wirth	12
Con Forms	49	Ingenieros Civiles Asociados	6	Peri	50	WSP UK	7
Conam	14	Interegger	8	Pochin	47	WTM Engineers	14

Lovat, Seli together in Russia

Lovat and Seli are supplying TBMs and equipment for two tunnel projects – Kuznetsvosky and Sochi – as part of a wider co-operation agreement in Russia they have with contractor Bamtonnelstroy.

For the Kuznetsvosky rail project in Siberia, the companies are supplying a 10m diameter TBM, which has reached the Far East port of Vanino. It is expected that assembly will be undertaken around June.

The supply contract was signed

in February 2008, and includes the TBM along with back-up, conveyor, rolling stock, ventilation, power line and segment moulds.

Geology along the a 3,890m along alignment comprises sandstone, siltite, crushed stone and basalts. No information was available on groundwater conditions.

The double shield has 17" discs on a cutterhead with maximum thrust of 17,088kN, speed of up to 6rpm and drive power of 4900kW.

Tunnel lining is 8.8m i.d., 1.5m



Above: Lovat, Seli supply TBM for Kuznetsvosky tunnel in Russia

long rings (6+1) with segments of 450mm thickness. Pea-gravel will be injection around the concrete lining.

At Sochi, major infrastructure investment is underway in advance of the 2014 Winter Olympics.

Seli and Lovat are supplying a 6.18m diameter TBM to the Russian contractor for tunnelling work in Sochi. The shield is due to

leave Italy and reach site by late May for start up in July.

Geology comprises mainly limestone and sections of porphyrites. No groundwater information was available.

The tunnel will be lined with 200mm thick segments to form 5.6m i.d., 1.8m long rings.

The contract for the Sochi TBM was agreed in January.

Mexico City plans for stormwater

Workers repair and maintain the deep drainage sewers in Mexico City in advance of the wet season. The tunnel system is to take up to 180m³/s of combined stormwater and sewage.

But long-term settlement in the entire valley where the capital is located has been reducing capacity and a new tunnel system – the Eastern Discharge Tunnel (Túnel Emisor Oriente) – is under construction.

The National Water Commission (Conagua) is developing the drainage upgrade scheme to both increase capacity and reduce flood risk by 2012. In total, the new 7m i.d. sewer will be 62km long with 24 shafts of 30m-150m depth, the majority being 12m diameter but some 16m wide.

Geology comprises sandy clay, gravel, tuff and pumice, and there are large boulders.

Six EPBMs are being used to

bore the tunnels – three from Herrenknecht (2 x 8.7m dia., 1 x 8.89m dia.) and three from Robbins (3 x 8.93m dia.).

The contractor is the Constructora Mexicana consortium, which includes Ingenieros Civiles Asociados,

Carso Infraestructura y Construcción (CICSA), Construcciones y Trituraciones (COTRISA), Constructora Estrella (CESA) and Lombardo Construcciones.

The contract value is US\$705M.



Photo credit: AP/PA Photos



Photo credit: AP/PA Photos

Left, Above: Work underway below Mexico City to repair and maintain the deep sewer system. A 62km expansion is planned that will be bored using six TBMs.

Bechtel gets Crossrail

Bechtel has been awarded the Project Delivery Partner contract for the US\$23.5bn Crossrail project which involves major tunnelling works through the centre of London. It is supported by Halcrow and Systra.

The US firm beat three shortlisted rival parties for the US\$590M contract, which is to help the client, Cross London Rail Links Ltd (CLRL), to meet standards, time and budget. The contract will also require Bechtel to provide extra key staff to support the core client team.

Construction of the East-West rail scheme calls for excavation of a total of 41.5km of 6m i.d. twin tube tunnels by TBM. Main construction works begin in 2010 for rail services to commence in

2017. The first tunnel drives are programmed to start in 2011, and planning so far has suggested seven TBMs will be required.

Bids for the Project Delivery Partner contract were submitted in January from four parties: Bechtel; Legacy 3 (a consortium of Parsons Brinckerhoff, Balfour Beatty Management and Davis Langdon Programme Management); Laing O'Rourke Holdings; and, a joint venture of Capita Symonds and Northcroft.

CLRL also recently appointed Transcend, the JV of Aecom, CH2M Hill and Nichols Group, to be Programme Partner for the scheme. The contract is worth approximately US\$148M, said the client (*T&T*, March, p11).

Bechtel and supporting

partners were shortlisted to be Programme Partner. The other shortlisted party was Legacy 3.

Last year, CLRL also chose the dozen firms that would be Framework partners and able to bid for design work: Aedas Group; Atkins; BDP; Capita Symonds; Halcrow; Hyder Consulting (UK); Jacobs Engineering UK; Mott MacDonald; Ove Arup; Parsons Brinckerhoff; Scott Wilson Railways; and, WSP UK.

In the construction phase of the

project, CLRL is led by chief executive Rob Holden, formerly chief executive of London and Continental Railways (LCR), which built High Speed One. In November, Terry Morgan, chief executive of Tube Lines, joins as non-executive chairman. Early development of the scheme, which secured Royal Assent last year, was led by Douglas Oakervee who is now interim non-executive chairman.

Contract award to finish S-C bores

A joint venture of Frontier-Kemper, J.F. Shea and Aecon have been awarded a contract to finish the partly-built Seymour-Capilano twin tube tunnels in Vancouver, which was stalled last year over an unresolved ground conditions dispute between Metro Vancouver and the previous contractor, Bilfinger Berger.

Metro Vancouver said it had awarded a US\$146M contract to the JV to complete the 7.1km long tunnels, which were about half excavated for the water treatment and supply project. Work is to start this month with completion scheduled by late 2012 or early 2013.

The client added that the original engineering design is to be used and also the two TBMs still underground, which were kept along with all other equipment when Bilfinger Berger's contract was terminated. The German contractor and Metro Vancouver remain in legal dispute over the contract due to ground conditions and safety claims, its termination, and also the withheld equipment.

Tunnelling on the drives stopped in January 2008 and Metro Vancouver terminated the contract in May. Metro Vancouver

said a court hearing has been set for 2011 but there is no trial date.

Frontier-Kemper, J.F. Shea and Aecon won the bid against one other compliant tender. Three JVs had been shortlisted from the prequalification stage, for which 15 firms were invited. Offers were to be submitted on both fixed price and target price approaches. The other shortlisted parties were the JV of McNally, Obayashi and Procon, and the consortium of Dragados, Seli and Schiavone.

Metro Vancouver said overall costs for the entire scheme were estimated to be US\$322M - double the earlier budget. Funds to complete the tunnels were recently approved, totalling US\$161M, including allowance for contingencies.

The client confirmed it intends to seek recovery of costs of completing the project from Bilfinger Berger, but the contractor is counter-suing for frustration, damages and costs.

Bilfinger Berger said its lump sum bid, in 2004, was close to client estimates. The next closest bid was US\$150M from the JV that has now won the contract to complete the tunnels (*T&T*, August 2008, p11).

Shanghai gets finishing touches

Tunnel fit-out work is underway to complete the Line 7 metro that runs from the centre to north west Shanghai. The 9km long tunnel is part of the line which will be 35km long with 28 stations. The line is to be opened, along with a battery of others, before the city hosts the

2010 World Expo. In the centre of the city, Line 7 interchanges with Line 4 at Dong An Road, and en route crosses a number of other metro lines. Further extensions of the line are planned to the south east. In 2010 the city will have another six lines added to its existing five.



Photo credit: Landov/PA Photos

Osterberg bores begin

Work on the Osterberg high-speed rail tunnel has got underway near Kalzendorf in Sachsen-Anhalt, Germany.

Drill and blast excavation of the twin, 2,072m long tunnels is being undertaken by a joint venture of Porr, Interegger, Ostu/Stettin and Jaeger Bau.

Tunnelling, which commenced in January from the east portal and was formally launched in February, is programmed to finish in late 2010. By the end of March the bores had advanced 489m and 391m, respectively.

The Osterberg project is to be completed in early 2012 for a budget of US\$160M set by DB

Netz, the new build arm of the national rail authority Deutsche Bahn (DB). It will form part of the Leipzig/Halle to Erfurt section of the North-South high speed rail link between Berlin and Munich, which will see trains travelling at up to 300km/h from 2017, reducing the travel time to four hours, it is planned.

There are three tunnels on the 123km long route between Leipzig/Halle to Erfurt – Osterberg, Finne (6.9km) and Bibra (6.4km) – all of which are in Sachsen-Anhalt. DB aims to have this section of the high-speed line commissioned by 2015.

Drill and blast excavation of Bibra tunnel started in October last year and the twin tubes are being advanced from both portals. The alignment through red sandstone is well above groundwater level. By the end of March they had both advanced approximately 817m from the west portal and 870m from the other end. The contractor is a JV of Marti Tunnelbau, Marti and Johann Bunte.

Excavation of the Finne tunnel began almost a year ago with the first of two 10.82m diameter Herrenknecht Mixshields (T&T7, September 2008, p7). Geology comprises weathered sandstone and lay-silt in a fault zone, and high groundwater for part of the alignment, though drier red sandstone elsewhere will enable some NATM construction.

Advancing from the south portal, the west and east tunnel drives had progressed 3,734m (over half way) and 1,146m, respectively, by the end of March with the TBMs S-419 and S-420. A Wayss & Freytag-led JV with Max Bogl and two units of Porr is building the tunnels.

Also in February, Porr celebrated along with JV partner Max Bogl the early completion of the 5.8km long TBM drive on Lot 3-4 (Munster-Wiesing) of the Lower Inn Valley rail line, in Austria. Excavation with the 13m diameter Herrenknecht Mixshield lasted 19 months, which was six months shorter than programmed.

W Ham sewer job start for Lovat TBM



Costain was last month preparing to get underway with a 3.4m diameter TBM drive in soft ground in east London with a Lovat shield for a flood relief scheme.

The contractor accepted the Lovat EPBM in January to excavate the 3,303m long stormwater sewer for the West Ham Flood Alleviation scheme being built by utility client Thames Water.

Geology along the alignment of the main drive, which has 15m-17m cover to the crown, comprises Woolwich & Reading Beds and the Upnor and Harwich Formations. Groundwater levels are expected to range from 10m-14m over the invert.

The cutterhead of "Theodora" has a maximum torque of 1,830kN, rotation speed of 4.8 rpm and is fitted with chromium carbide coated rippers and scrapers. Its drive is hydraulic with two electric motors and variable displacement pumps.

Lovat will also provide technical

assistance and spare parts during the tunnelling stage of the 2.87m i.d. stormwater sewer job.

The project also includes five shafts to be built in the waterbearing ground by both caisson and underpinning methods. In addition, microtunnelling on the scheme will see slurry TBM excavation of approximately 2,500m of 1.2m i.d. bores along with 19 shafts.

The client plans to have the full scheme in the London Borough of Newham completed by the end of 2010.

The TBM (MP132SE) supplied to Costain is Lovat's 250th shield and becomes the fifth held in stock by the UK contractor, which bought its first machine from the Canadian manufacturer in 1987.

Lovat said it has designed and built TBMs that have completed more than 700 projects since the business began in 1972.

In March 2008, Lovat was acquired by Caterpillar (T&T7, April 2008, p13).

Impregilo JV to open Ingula

A contract for major tunnelling works on the Ingula pumped storage scheme in South Africa has been won by a joint venture led by Italian firms Impregilo and CMC

Tunnelling works include the underground powerhouse, a 2km headrace tunnel to the upper reservoir and a 2km long tailrace tunnel to the lower reservoir. In addition, the underground package includes shafts, surge tanks and penstocks.

The construction contract was worth approximately US\$795M, said Impregilo. As part of the contract, the JV – in which the contractor has a 40% share – will also undertake dam construction for the upper and lower reservoirs.

South African utility Eskom Holdings is developing the pumped storage project in the border area between KwaZulu-Natal and the Free State, about 350km south east of

Johannesburg. The client has scheduled the plant to come into service in 2013.

The project was formerly named Braamhoek but was rebranded two years ago. That year, contractor Murray and Roberts completed a 1.2km long exploratory tunnel. Excavation started in 2005.

Geology in the project area was found to be more complex than expected in a Karoo Supergroup sedimentary sequence, and mudrocks were frequently intersected in boreholes, though the rockmass is expected to be relatively unjointed.

An South African-Italian JV, CMC Mavundia, built the access tunnel, which includes parts of the machine and transformer caverns. A feasibility study for the project was recommended just over a decade ago and completed in 2003. Design is by the Braamhoek Consultants JV, led by Knight Piesold and Stewart Scott.

We know that you can



No matter if you're the world's largest or smallest contractor, a veteran or a newcomer; we have the tools to help you develop your business. To make it easy for you we've gathered it all in one place.

Start your development right away at atlascope.com/rock

Committed to your superior productivity.

www.atlascope.com/rock

Atlas Copco



Robbins speeds progress in Delhi

Robbins has claimed the fastest weekly progress rate achieved with any of the 14 TBMs on Phase 2 of New Delhi metro – 168 rings, or 202m, with the first of its two shields to complete excavation.

The 6.52m diameter EPBM, being driven by JV contractor Continental Engineering Corp (CEC/Soma, achieved the reported fastest advance rate during its second 1km long bore, which completed on 5 March).

The JV is working on contract BC-16 between Udyog Bhavan and Green Park. The Robbins shields were built to an EPB design by Mitsubishi Heavy Industries (MHI) and are

undertaking half of the tunnelling required – the parallel tunnels between Jor Bagh in the middle of BC-16 and Udyog Bhavan at the contract boundary with BC-15.

On the other side of Jor Bagh, a pair of 6.54m diameter Herrenknecht shields (S-411, S-412) have been employed by the JV to drive twin tunnels. They were launched from INA box station.

Geology along the alignment comprises sandy silt, silty sand and gravels with groundwater pressures generally up to 2 bar. Cover is approximately 15m.

In early 2007, the JV was awarded a 40-month contract by the client, Delhi Metro Rail Corp (DMRC), to design and build the

tunnels, which total approximately 4km in length.

The first Robbins TBM was launched from Jor Bagh station in May last year and finished its first 1km long drive with an intermediate breakthrough, at Race Course station, in late September. On that leg, the TBM built up to 19 rings per day – more than expected – and with 90% availability, the JV commented, noting the contribution from electric motors in continuing the drives in mainly soft clays.

The sister shield achieved up to 118 rings, or 142m, per week during its first 1km long drive, which fully got underway after the five gantries were installed in

Above: Delhi metro extension; (top, bottom) Robbins TBM at Race Course, Herrenknecht TBM at Jor Bagh

October 2008. It has been relaunched from Race Course and is scheduled to complete the second bore next month.

In total, the metro scheme involves approximately 16km of tunnel as part of about 30km of underground works, including box stations.

Earlier this year the last of the 14 TBMs required for the metro expansion was launched on the Airport Express Link section of the scheme (*T&T*, February, p7).

Most TBM drives in Phase 2, though, are in the corridors from Central Secretariat (CS) to Badarpur and to Qutub Minar, the latter including BC-16. The 5.7m i.d. and 5.8 i.d. tubes on the scheme are lined with segmental rings (5+1) of 275mm thickness.

DMRC aims to have all tunnelling completed by December. Next year the city will host the Commonwealth Games.

Tunnel fatality at Allain Duhangan

A worker was killed by a rock fall in a tunnel last month at the Allain Duhangan hydro power project under construction in the state of Himachal Pradesh, in India.

Two other subcontractor workers suffered minor injuries in the accident, said project co-owner SN Power.

Last year the company launched a review of health and safety data at the project because of under-reporting of fatal accidents, which

was discovered from an audit report in November 2008. The audit showed there were two deaths that had not been properly reported and, by then, there had been 11 fatalities on the project since work began in 2006.

Tunnelling works on the project include adits and an underground powerhouse at the confluence of two rivers. Poor geology, causing soil slides and loose rock, increases risk in the local

Himalayan region, said SN Power.

The Norwegian company has launched an investigation into the fatal incident on 10 March, which comes a few months after it seconded international staff to the project to help improve project management, including health and safety systems and procedures.

SN Power has a 43% holding in project developer Malana Power, which is a joint venture. It

has an agreement to acquire a 60% controlling share and as such took action when it learned that information coming to it was not full and complete, as it described. The main partner at present is NLJ Bhilwara Group with a stake of 45%, and the minor investor is the International Finance Corp (IFC).

The Norwegian company is a JV of energy utility Statkraft and investment firm Norfund.

First bite for Brisbane Airport Link

Excauation work on the Airport Link and Northern Busway in Brisbane has got underway with the start on site of the first of 11 roadheaders scheduled to work on the major road project, which will also see two TBMs arrive next year.

The contractor, a joint venture of Thiess/John Holland, is due to bring the second Sandvik MT720 (formerly Alpine Tunnel Miner ATM 105) roadheader to the Truro Street site by June. Later, a further three units will work from the site.

The entire fleet of roadheaders will also include four working from the Kedron site and two from Bowen Hills. Driving at depths of up to 35m, the contractor expects each roadheader to advance up 3m-6m per day, depending on ground conditions.

Geology in the area is dominated by the Neranleigh Fernvale Beds, which are regionally metamorphosed rocks, including hardened shales, greywackes and quartzites. For hard rock, the MT720 uses 72 picks, and 57 for soft rock.

The JV is performing the design and construct contract for the concessionaire, BrisConnections, on a fixed-price, fixed term basis contract for completion by 2012.

BrisConnections was awarded the 45-year toll link concession by the Government of Queensland. In addition to Thiess and John Holland, members of the consortium include Macquarie Capital Group, Arup and PB.

A pair of 12.48m diameter hard rock Herrenknecht TBMs were ordered last year with contract value of more than US\$64M. The shields are to be delivered to site late this year for launch by mid-2010 (T&T, October 2008, p12).

The TBMs will drive parallel tubes southbound from Toombul to Bowen Hills for the project's 5.25km long toll tunnel, which dominates the 6.7km long link. The Airport Link and Northern Busway is part of Brisbane City Council's TransApex plan.

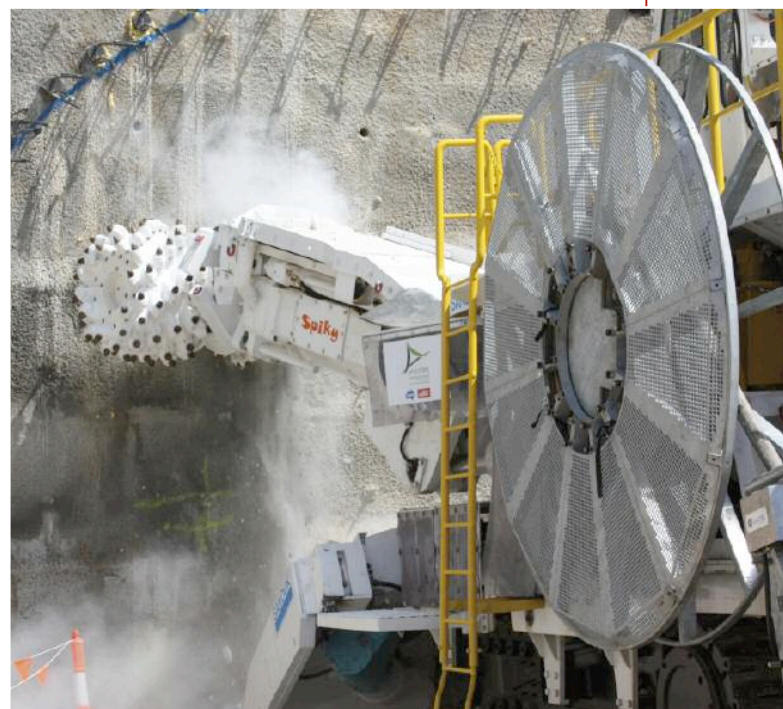
In total, the link calls for approximately 11.8km of tunnel excavation – the balance mostly

bored by roadheader, and there will also be some cut and cover construction. Cross passages spaced at 120m nominal intervals. Roadheaders will also be used for the 3km long road (half in tunnel) between Windsor and Kedron on the Northern Busway.

Separate to the technical progress being made on the major project, BrisConnections continues to have difficulties with an investing body in the unit trusts that provide financial support to the venture. The investor, Australian Style Investments Pty Ltd (ASI), has called on other investors to vote to wind up the two key unit trusts supporting the project, which are managed by BrisConnections Management Co Ltd.

While making the case that winding up does not relieve unit trust holders of their obligations to progressively provide the balance of financing required by the partly-paid security, or "staple trust", when called at key stages, the management firm noted a recent legal setback. The Supreme Court of Victoria did not back its claim that ASI's move was invalid and instead ASI should be wound up.

The reasons for the judgement were not immediately available, and the management firm has,



Above: First of 11 roadheaders for Brisbane's Airport Link tunnels

consequently, advised unit holders that ASI's requested extraordinary meetings were set to proceed, on 9 and 14 April.

However, it further noted that legal challenges are continuing in Queensland and Victoria.

At the end of March, the venture received note of continued financial and other backing from the Macquarie Group bank, which is both an

underwriter and a investor through the unit trusts.

The bank noted its further purchase of stapled units and its provision of US\$66.3M in a previously agreed bridge facility. It also stated that legal action had been initiated to ensure all parties fulfil contractual obligations. The next calls on funding from unit trust holders is late April and in January 2010.

Perschling final breakthrough

Breakthrough last month at Raingruben rail tunnel, in Austria, saw Strabag complete the main excavation work on the Perschling project for the track arm of the national rail authority, OBB Infrastruktur Bau.

The 12.98m diameter Herrenknecht single shield (S-319) completed the 2,120m drive on 11 March after being launched in late May last year. In total, the Raingruben tunnel will be more than 2,730m long, including a 408m long covered section between bored piles.

Strabag is working on Lot 3 of the 42.3km long railway line that

OBB is building in east Austria between Vienna and St Polten. Work began in 2005 and is scheduled for completion this year. Design work for the client was done by ILF Consulting Engineers.

The 13km long Perschling stretch includes three tunnels - Raingruben, which is farthest west, and the Stierschweiffeld and Reiserberg tubes which are located in the middle and west of the project section, respectively. Just over half of Lot 3 is built in bored and covered tunnel. The tunnels will carry twin rail tracks.

Geology along the alignment comprises marl, siltstone and

sandstone. The TBM has maximum cutterhead torque of 13,500kNm and 17" discs. The bore, which has an excavated diameter of 13.03m, is lined with 1.8m long concrete segmental rings (5+1) of generally 300mm thickness, and a final concrete lining of 300mm thickness.

The TBM completed its first drive on the 2,857m long Stierschweiffeld bore in April 2007 after starting the drive in the fourth quarter of 2005. Excavation of the 1,307m long bore for the Reiserberg tunnel started in August 2007 and the TBM holed through in February last year.

China wins for Atkins, Cowi

Consultants Atkins and Cowi have been awarded key tunnel design roles in separate major transport projects in China – parts of the Express Rail Link (XRL) from Hong Kong and the Shatin-Central Link project, and the immersed tube section of the Hong Kong-Zhuhai-Macau link, respectively.

MTR Corp has awarded Atkins the contract (C802) to undertake detailed design of twin tube tunnels and associated works for the “south” section of XRL, which is to extend approximately 15km from Kowloon, in Hong Kong, towards the mainland border, stopping approximately 10km short.

Atkins added that it is also involved in the contract (C803) to undertake detailed design work in this “north” gap section.

Atkins undertook preliminary design work for the tunnels, which it said would be bored through complex ground conditions in an urban area to a fast-track programme.

Construction methods will include drill and blast, shield and cut and cover. The approx 25km-26km long section is to be completed by 2014-15.

Tenders were submitted in September last year. MTR Corp took over the project upon its merger with Kowloon-Canton Railway Corp, almost a year and a half ago.

Beyond the border, the link will run to Shenzhen and Guangzhou provinces. Part of the northern section, between Shenzhen and Guangzhou, is already under development and is to be operational by 2010.

Separately, in Shenzhen, MTR has just signed a concession agreement for Phase 2 of Line 4 of the city's metro on a build, operate and transfer (BOT) basis for 30 years.

The 15.8km long extension – almost a third of which will be in tunnel and with two underground stations – is to be operational by 2011.

MTR has been already working

Bids for Seattle Uni Link bores

A joint venture of Traylor and Frontier-Kemper have submitted the lowest bid for a package of tunnelling work on Seattle's University Link between the University of Washington and Capitol Hill.

The JV bid US\$309.2M to construct the twin tunnels plus part of the University of Washington station. The client, SoundTransit, will do a bid review to confirm the award.

The second of the two submitted tenders was US\$360.8M from JCM U-Link Joint Venture.

Tunnel excavation is to be undertaken with two TBMs driving from University of Washington.

The University Link has a development budget of US\$1.9bn and is due to be operational from

2016 as an extension to the Link light rail, which begin services later this year.

At the end of last year a contract was awarded to Condor Johnson for site preparation for the area where a TBM will pass below Interstate 5. The bid was US\$19.4M, which was two-thirds of that estimated in planning.

In early 2010, a contract is to be awarded to bore twin tunnels from Capitol Hill onwards to the Downtown Seattle Transit Tunnel.

In January this year, the Federal Transit Administration (FTA) gave a US\$813M grant to SoundTransit for development of the University Link.

The client is also planning Sound Transit 2, which would extend the University Link by 20km by 2023 as part of a larger, 57km expansion plan.

Aker takes over Wirth

Aker Solutions has taken majority control of Wirth GmbH with an increase in its stake to a qualified majority holding of 75.1%, and the remaining stock is to be obtained in stages over the next few years.

The ownership is held by Norwegian group Aker's subsidiary Aker MH, which took a 50% stake in Wirth in August 2007 with an option to buy the remaining half of the Germany-based business which manufactures TBMs as well as drilling equipment for the oil and gas sector. The companies have had a business relationship for nearly two decades, they said.

In late January, the company said it made an agreement to buy the remaining 50% and last month it received regulatory approval for the takeover move. Wirth is now part of Aker Solutions.

A year ago, Aker Solutions became the rebranded name for the Aker Kvaerner business.

on the scheme over the last few years. The new package involves also taking over operations on Phase 1 of the line – opened in 2004 – from about 2010.

Back in Hong Kong, MTR also awarded Atkins the preliminary design contract for the North-South Line section of the Shatin-Central Link project.

The 6km long extension, from East Rail Line, is mostly underground between Hung Hom and Admiralty stations, involves excavation below the harbour and is due to be completed in 2019.

The consultant is also working on the East-West Line, which is the other part of the project.

Distinct from the land links, the Chinese Government has

launched the preliminary design work for a major coastal road scheme from Hong Kong to Zhuhai and Macau. Last month, the Government awarded a contract for design of the link as a 30km long bridge and tunnel connection.

In the nine month contract, Cowi is the joint venture partner focusing on design of the 5.6km long immersed tube tunnel, which will be approximately 40m wide (three lanes in each direction) and placed at depths up to 38m.

The other partners in the JV are Arup, the Chinese Highway Plan and Design Institute (HPDI), Shanghai Tunnel and Design Institute (STEDI), and the 1st Harbour Design Institute.

NFM push into India

NFM Technologies has taken forward its proposed strategic push into India by stepping up its planned co-operation with Barath Earth Movers Ltd (BEML) to give it exclusive rights to be the principal supplier of TBMs to the equipment manufacturer in the continental market and also south east Asia.

Late last month NFM signed a Memorandum of Agreement (MoA) with the manufacturer, which builds upon and takes forward their Memorandum of Understanding (MoU) agreed seven months ago.

There are no TBMs within BEML's mining and

construction division, which focuses on loaders, dumpers, sips and winches for underground activities. BEML is active with joint ventures throughout its portfolio.

NFM said that state-owned BEML was a major strategic partner with which it believes it can make significant progress into the growing infrastructure market in India, especially for underground works. BEML is controlled by the Ministry of Defence.

In a statement, NFM said: 'At a time when infrastructure requirements are rapidly increasing, the MoA seals an exclusive partnership'.

Whatever your challenges are

in the creation of sustainable new space underground, MEYCO® provides one-stop, customized solutions through its unique blend of innovative product technology, specialized equipment and engineering know-how.

www.meyco.basf.com



The Chemical Company

Expanding horizons

underground

MEYCO

Fehmarn design JV picked

A joint venture of Ramboll Denmark, Arup and Tunnel Engineering Consultant (TEC) has been awarded the tunnel engineering consultancy contract for the possible immersed tube to be built across the Fehmarn Belt between Germany and Denmark.

Work on the tunnel study is to be supported by subconsultants that backed the bid - WTM

Engineers, HTG Ingenieurburo fur Bauwesen, Wilkinson Eyre Architects, Schonherr Landskab and Oriental Consultants.

The road and rail crossing is to be 18,565m long, plus ramps. Construction is programmed to start in 2012 for the link to open six years later.

The tunnel would consist of two 10m-wide cells for road

traffic and also two 6.37m-wide cells for single-track railways. Construction work will also involve establishing a ventilation island in the middle of the crossing.

The Ramboll, Arup, TEC JV beat two rival shortlisted groups to take forward the tunnel option in competition against a cable stayed bridge alternative, which was awarded to another consortium in a separate tender competition.

Both options are being taken forward as it is not yet established what would best suit the geotechnical and environmental conditions, which are currently starting detailed studies.

The client, Femern Baelte A/S - a subsidiary of Sund & Baelte A/S, which built and operates the Storebaelt and Oresund crossings - said it would develop the tunnel and bridge designs for Fehmarn until a marked, definitive advantage for one becomes apparent.

Previously, the client said the tunnel option was expected to continue to about 2011 - the year before construction of the chosen alternative is due to commence.

In pre-survey analysis last year, the bridge option was calculated to be the cheaper option. The

bridge alternative was estimated to cost US\$5.74bn (2007 currencies) versus the tunnel budget of US\$7.35bn.

Femern Baelte A/S' chief executive, Peter Lundhus, said all bids from the shortlisted groups, for the tunnel and bridge, were technically qualified and those that were financially advantageous were the ones chosen. Details of the bid structure were not available.

The bids were received in December (T&T, January, p12).

The losing consortia for the tunnel study were a partnership of Grontmij/Carl Bro, Faber Maunsell, Bung, Grontmij/BGS and Capita Symonds, and a JV of Cowi and Obermeyer Planen + Beraten (supported by subconsultants Flint & Neill Partnership and Dissing + Weitling).

The latter group was also almost the same as the JV that won the bridge study, beating three competitors.

Denmark and Germany signed a Treaty last September to finally build the fixed link.

Concept planning to create the crossing was underway almost two decades ago while the first tunnel link in the area - Storebaelt - was under construction.

Big Dig ceiling fall claims settled

Settlement agreements with designer Gannett Fleming and epoxy glue producer Sika last month has completed the claims brought by Massachusetts over the fatal ceiling collapse, in 2006, in the Big Dig Tunnel in Boston.

Massachusetts Attorney General's Office said Gannett Fleming was the designer for the section of tunnel ceiling that collapsed, and it has agreed to a US\$1.725M settlement in three parts: US\$1.525M into the Central Artery Statewide Road and Bridge Infrastructure Fund; US\$50,000 to the City of Boston; and, it will forgo US\$150,000 of payments from Massachusetts Turnpike Authority (MTA).

The settlement with Sika, which sold the epoxy to Power Fasteners, Inc, will see the manufacturer pay US\$200,000 into the Fund.

The settlement agreement is with the Commonwealth, represented by the Attorney General's Office, and the MTA and Massachusetts Highway Department (MHD).

At the end of last year, the criminal manslaughter indictment against anchor adhesives manufacturer Power Fasteners was dismissed as part of a compliance agreement, and civil claims were settled for US\$16M with the Commonwealth and City of Boston).

Claims against structural engineer Sigma Engineering International, Inc, and materials inspection firm Conam, Inc, have been dismissed, the Attorney General's Office added last month.

In July 2006, a ceiling panel fell in the I-90 connector tunnel and struck a car, killing a woman passenger, Melina Del Valle.

Attorney General Martha Coakley said in a statement: 'The resolutions we have reached with the various companies involved in the project appropriately hold accountable those responsible for the problems in our tunnels, ensure that similar problems will be prevented in the future, and provide the Commonwealth with the necessary funds to maintain the tunnels and other transportation infrastructure in the years ahead.'

The Attorney General took office in January 2007 and in addressing problems with the Big Dig project - including the fatal ceiling collapse - she has been able to obtain a total of US\$610.6M in recoveries from the resolved civil claims, including those that were litigation-related.

Other recoveries over 2007-8, the Attorney General's Office said, were: US\$58.5M in AIG state settlement related to workers' compensation insurance overcharges; US\$50M in Aggregate Industries settlement over false claims for adulterated cement; US\$458.2M in Bechtel/Parsons Brinckerhoff settlement over ceiling collapse, wall leaks and various design errors and problems; US\$21M in Modern Continental Construction Co's damages settlement; and, US\$5M in the settlement for damages with Newman Associates, Inc, and Renner Colony, LLC.

Euroform wins Laos contract

Italian firm CMC has awarded a supply contract to Italy-based Euroform to supply the segment moulds and carousel for tunnelling works on the Theun Hinboun hydro power project in Lao PDR.

Euroform, which is a subsidiary of Herrenknecht, is to supply four sets of moulds with wheels, including the pneumatic vibrators set, plus one complete carousel for segment production.

The equipment is to be delivered from Euroform's plant in Gessate, Milan, to the construction site by June.

Production will be able to make four-to-five segments per hour from the carousel.

The tunnel lining has been designed with six, 280mm thick segments to form 7.46m o.d. rings of 1.6m length. The invert will include housing for back-up rail assembly. Assembly is bolts between segments and bi-block to join rings.

CMC is undertaking the civils works for the Theun Hinboun expansion project, and tunnelling work was subcontracted to a subsidiary of Vietnamese construction group Cavico. The expansion project is being developed by Theun Hinboun Power Co (THPC), a JV of Electricite du Laos, GMS Power of Thailand and Norwegian utility Statkraft.

NFM TECHNOLOGIES. TUNNEL BORING MACHINE MANUFACTURER.



OUR MECHANICAL EXPERTISE WORKING FOR YOUR PROJECTS

NFM Technologies is a manufacturer of tunnel boring machines from 4 m to over 15 m in diameter, for any type of geology, making large-scale projects possible for rail, road or water infrastructures.

NFM Technologies' broad range of competences as an OEM in the cutting-edge mechanical sector means that it can propose innovative technical solutions, integrating specific requirements for each project and guaranteeing a high level of equipment reliability.

Whether for improving access to regions, developing infrastructures, or improving quality of life, our expertise is available to meet with your needs.



Hard-rock TBM



Soft ground TBM



Dual mode TBM



NHI GROUP

Creator of underground spaces

TUNNELS AND GALLERIES: Rail | Road | Water

www.nfm-technologies.com

The Achrain Tunnel – a bridge underground

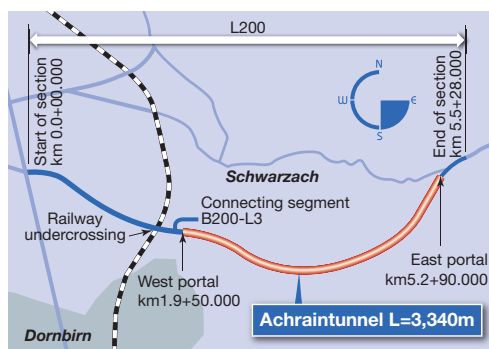


Figure 1 - Project site map

Helmut Westermayr, project director for Beton- und Monierbau describes construction of the Achrain road tunnel in Austria

Austria's US\$77.3M Achrain Tunnel is the heart of the new route for the L200 motorway, which runs from the future Dornbirn North roundabout into the Bregenzer Forest and provides a direct connection to the A14 Rheintal motorway (figure 1).

The Achrain Tunnel has a total length of 3,340m, including a 35m long open cut approach section in the east, and a 75m long one in the west. It consists of a 120m - 190m² cross sectional area three-lane main tunnel with a 5.2% gradient and an escape tunnel running parallel to it with a length of 3,165m. In order to define the geological conditions along the alignment, the emergency escape tunnel for the road tunnel was bored in 2000 and 2001 as a pilot tunnel using a 3.9m diameter TBM.

As well as the main tunnel, along with niches and crossovers, the construction lot also includes east and west service centres, the removal of earth deposit to an approx. 1.8km long area above ground and the partial reconstruction of the existing pilot tunnel.

The Joint Venture Achrain Tunnel, consisting of Beton- und Monierbau, Alpine-Mayreder, and Jäger Bau, was awarded the contract on 3rd June 2004 and construction began officially on the tunnel soon after on 22nd June 2004.

Excavation was carried out by either drill and blast, or roadheader, where suitable for the ground conditions, using NATM followed with a fast ring closure. Lining comprised lattice girders every 1.7m on average, with a 150 - 250mm primary lining of sprayed shotcrete according to ground conditions, and a 300 - 400mm cast in place concrete lining. Rockbolts were applied, again, according to the local geology.

Tunnel construction technique

Excavation was predominantly carried out in the "Weissachschichten", a succession of variegated marls containing layers of sandstone. Those sediments belonging to the Lower Freshwater Molasse were largely marl interspersed with sandstone layers of various thicknesses.

As a result of the high content of active clay minerals and the inherent swelling potential in the marls in the Weissachschichten, the construction of the pilot tunnel had been rather problematic, from a tunnelling point of view.

With this in mind, for the main road tunnel the designer included a deep invert arch in ground highly susceptible to swelling. A shallow invert arch was used in areas, where fewer swell-able clay minerals were present (figure 2 and 3).

By using the appropriate reinforcement in the invert, the swelling pressure can increase

to as much as 600kN/m² without jeopardizing the stability of the tunnel.

In the case of the shallow invert arch, the excavation cross-section amounted to 125m², and 150m² for the deep invert arch; the parking bay niche had already reached an impressive 190m².

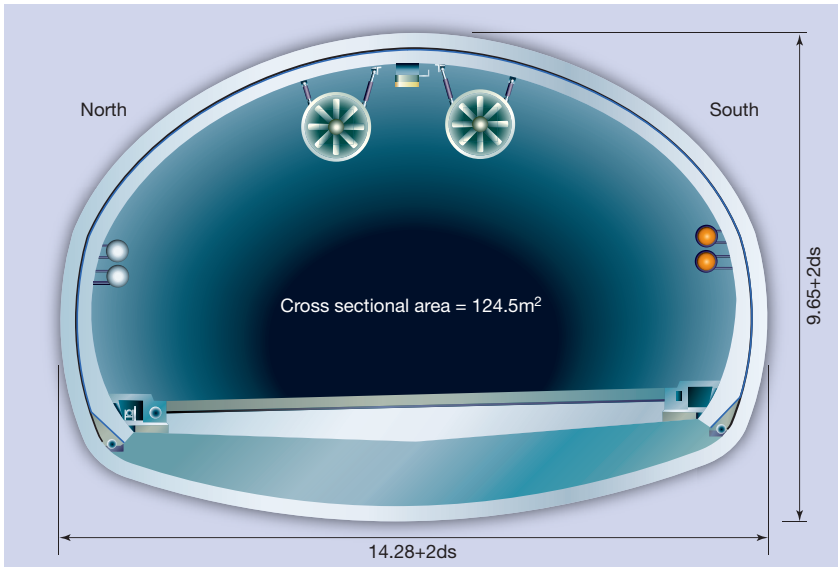
Furthermore, the time schedule and distance criteria for tunnelling specified by the designer had to be strictly observed. In the case of the deep invert arch, the maximum distance between the top-heading face and the bench face was 150m, and from the bench face to the invert a further 20m.

In addition, the shotcrete invert arch had to be applied two months after the crown excavation, and the reinforced cast concrete invert arch a further two months later. The entire inner lining had to be built two months later again.

Longitudinal breaks in construction were

Table 1:

Project	Achraintunnel Road Tunnel
Region	Österreich, Vorarlberg, Dornbirn, Austria
Client	Vorarlberg Provincial Government
Design	IGT Ziviltechniker Gesellschaft m.b.H., Salzburg
Construction management	Department of road construction Feldkirch
Contractor	JV Tunnel Achrain
JV-partners	Beton- und Monierbau/Jäger Bau/Alpine Bau
Supervision	JV Spirk - 3G - iC
Geological documentation	Dr. Werner Furlinger, ZT Büro für technische Geologie
Geotechnical measurements	AVD Vermessung ZT GmbH, Dornbirn
Length	3,340m
Cross section	125 - 190m ²
Construction method	Drill & Blast, roadheader, NATM
Project duration	June 2004 - October 2008
Opening	January 2009
Contract sum	US\$77.3M



Above: Fig 2 - Typical cross-section for the shallow Invert

Right: Fig 3 - Typical cross-section for the deep Invert

Above Right: Pic 1 - Bridge-ramp to the tunnel face

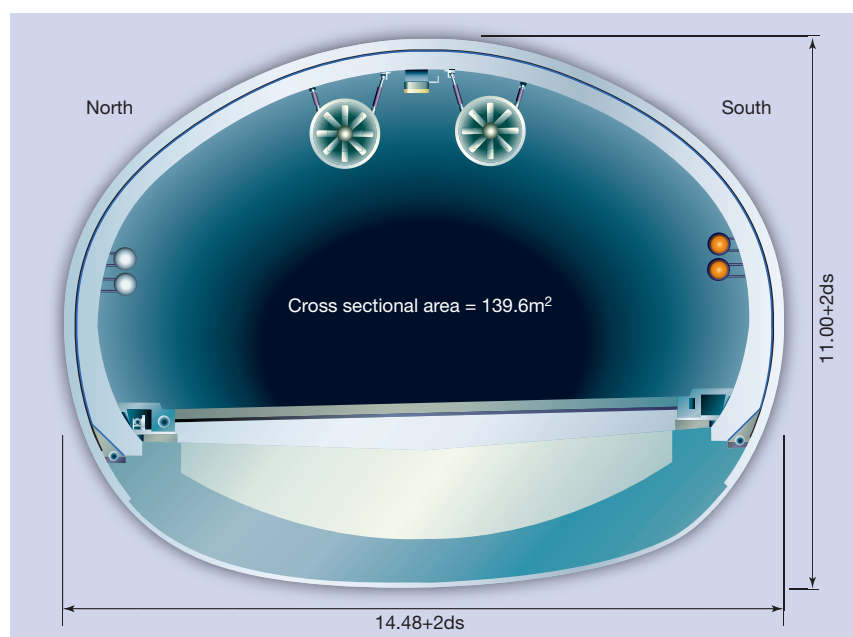
not allowed in the benches or in the shotcrete invert arch. Also, the reinforced invert arch also had to be constructed in one process, i.e. without a longitudinal joint.

Estimations on the construction timescale were researched thoroughly to ensure maximum cost efficiency during tunnelling. The simultaneous completion of the tunnel inner lining had to be coordinated with the progress of the tunnel drive and defined timescale.

Optimizing progress called for concreting in weekly shifts with one team concreting a 12m long invert arch, or arch block alternately every second day. This method of construction with consistently equal working cycles quickly proved efficient. There was enough time for necessary preparation and reworking, which also proved to be advantageous in maintaining quality.

The tunnel bridge

The simultaneous construction of the inner lining without halting the excavation progress called for the continuous work on the invert to be bridged on a large scale. To achieve this, a 52m long motorised steel bridge was brought in, which was available in time for the start of tunnelling. With both ramps the bridge had a total length of 89m and with all additional equipment weighed



approximately 300 tons (figure 4).

The tunnel bridge served, as mentioned, to bridge the invert workspace over a length of 45m (including ramps) and to allow for vehicles to drive over it with a total weight of a maximum 70 tons, with only one vehicle allowed on the bridge at any one time.

The basic construction of the bridge was a solid steel structure consisting of two bridge sections and two ramps, which were hinged together. Both edges of the access ramps were equipped with slat-like wedges. As well as both bridge sections, there was a separate walkway on the right-hand side,

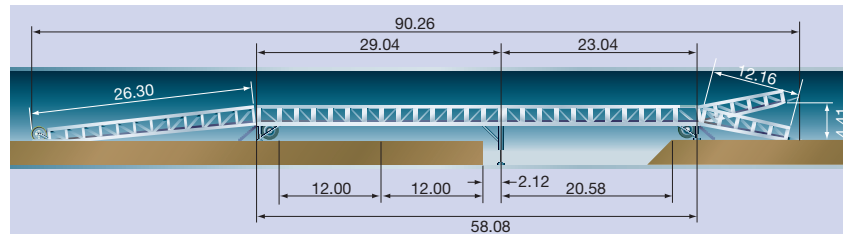
which was accessible via stairs.

The bridge was operated using two electrically driven 11kW motors, with steerable heavy-duty wheel axles built into both ends. The front part of the bridge stood on the muck deposit, which was suitably compacted. The rear section of the bridge stood on the already concreted invert with a transverse gradient of $\pm 2.7\%$ to the middle of the tunnel.

It took approximately 10 minutes for it to travel a 12m section.

To enable construction vehicles to drive over the bridge, as well as during concreting and bulkhead forming, the wheeled undercarriage was raised and the support cylinders took the load. Supporting legs were therefore available left and right, next to the axles. The supporting leg bracing was performed by supporting discs, with the support discs in the earth deposit area having a diameter of 1150mm for extra load spread, while all others had a diameter of 800mm.

The middle of the bridge was hinged and



Above: Fig 4 - Longitudinal section of the bridge



GAUTRAIN SITE DEMOBILIZATION



Bombela Civil Joints Venture consortium, that consists out of Bouygues Civil Works, Murray & Roberts and SPG is currently busy with site demobilization and the following equipment / plant is available:

- COGEMACOUSTIC Tunnel ventilation fan: 30 to 250 kW
- Shotcrete Robot PUTZMEISTER model: PM407 - PM500
- PAUS Dumper ITC 10000 20t payload interchangeable with Concrete mixer CIFA
- Basket NORMET 9915 BA
- LHD GHH Model 6.3
- Batching Plant COUVROT and ARCEN: capacity from 40 to 60 m³/h
- Rolling Stock 900 MM
- FERMEL Utility vehicle
- BOART LONGYEAR Charging Unit
- Grout Pumps CLIVIO
- Agitator Hopper SECATOL: 7m³ - 10 m³
- Gantry Crane: 30 - 40t
- Side tipping bucket GERSTADT. Capacity (3m³ - 4m³)



For more information contact:
christophe.ollivier@bombelacjv.com
 Telephone: 0027 (0)11 997 8141
 Mobile: 0027 (0) 83 632 9116
 Address: 22 Milky Way Avenue
 Linbro Business Park
 Johannesburg
 P.O. Box 1177
 South Africa





Bridge center pillar

supported by 2 hydraulic props, which extend telescopically to deal with the two different invert cross-sections – deep invert and shallow. The middle prop was oscillatory and was only stabilised by retaining cables, which sagged freely, when driving up the bridge.

The space in front of the middle prop (approximately 22m) was used to prepare for concreting, i.e. in this area the banked up, temporary road surface was removed by excavator and wheel loader

In the space behind the middle prop there were two work bays, each 12m long, one of which was a concreting bay, separated by a transportable steel bulkhead formwork, and the other was the reinforcement bay.

The access ramps were designed with the wedges on the bridge so that the maximum ramp gradient does not exceed 13%. The front ramp could be raised using two hydraulic cylinders to a height of maximum 2m. The rear ramp was raised on hydraulically actuated supporting wheels.

Under the rear bridge section, the concreting device was conveyed up and down by a chain hoist. Solid U-rails were also welded onto the outside of the bridge, allowing the base frame of the concreting device to travel by trolley. One third of the base frame could be walked on in order to be able to reach the control panel and connect/disconnect the equipment on the longitudinal feed. The concreting device consisted of three conveyor belts GB 500 including;

- one feeder belt, this could be fed via the concrete mixer
- one transfer belt, reversible
- one distribution belt, reversible

This permitted the placing of concrete as required in the entire area.

The vibration opening, with an additional operations platform, was attached to the base frame of the bridge by two tension rods. The vibrating beam and operations platform was equipped with a carriage on the side and ran on the longitudinal beams.

These longitudinal beams, in the shape of solid profiles to which the side shoulder formworks were mounted, were hinged to the bulkhead formwork and formed a unit.

Following the invert arch, the mass concrete was then poured and compaction was carried out by six immersed vibrators.

Both beam trolleys travelled on the same beams as the base frame of the concreting device for transportation of bulkhead formwork. For both cross-section profiles, two different bulkhead formworks were required.

1) Bulkhead formwork for the “shallow invert”: A one-piece formwork, with attachment points above left and right for both vibrator panel carriage beams. Two lifting jacks were fixed to the formwork underneath for height adjustment.

2) Invert formwork for the “deep invert”: A two-piece formwork; both halves were connected by three spigots.

The distance of deep invert arch came to exactly 1,537m from a total of 3,235m of mined tunnel, almost half the length.

The tunnel was broken through in March 2007 and the inner lining was completed in September 2007 – about 6 months later. The eastern open-cut and the attached service building had also been concreted by the end of 2007.

Since April 2007, the pilot tunnel, so far used for ventilation, was completely renovated and converted into the future escape tunnel. Work to fully fit-out the tunnel began in February 2008. After the completion of the fit-out, the tunnel was officially opened for traffic on 29th January 2009 with an opening ceremony.

Summary

Observing a construction schedule, which had already been drawn up at the estimation stage, and carrying out sound preparation lead to a linear construction site largely characterised by the lean allocation and economical use of resources. Despite the simultaneous excavation work and construction of inner lining, only 50 men were employed in the tunnel.

This parallel operation was only made possible by the bridge that was constructed so that it could be used as formwork and equipment bearer and as a concrete distribution beam at the same time.

Construction conditions were, of course, also appropriate and the inner lining could be constructed without obstruction from ventilation ducts, as the pilot tunnel was used for ventilation.

Last but not least, the constructive interaction between clients, designer, site supervision and Joint Venture produced the successful conclusion to construction that had been hoped for.

T&T



BORING THROUGH Future

**KUZNETSOVSKY
Railway
Tunnel
Project
RUSSIA**



SELI

www.selitunnel.com

Asbestos isolation

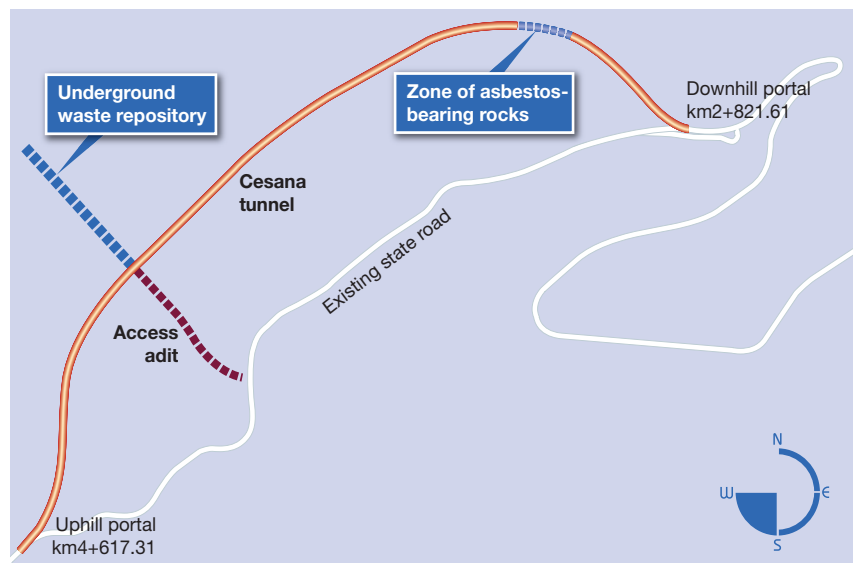
C. Alessio & G. Kalamaras of A&K Geotechnical Engineering, S. Pelizza & D. Peila from Politecnico di Torino, and C. Testa & P. L. Carlucci of ANAS SpA, explain how an underground repository will be used to store a zone of asbestos that has halted excavation on the Cesana road tunnel in Italy

The Cesana tunnel, located close to the Italian-French border in Piedmont (North West Italy), is the main structure on the SS24 road improvement works that were planned for the XX Winter Olympic Games. The tunnel has a length of 1860m and is located between a 370m long artificial tunnel and the 1280m long Claviere tunnel along a mountainous road which leads to the picturesque resort. Construction by the Italian-Spanish consortium SIS (SACYR S.A., INC General Contractor S.p.A. and SIPAL) started in March 2005.

Due to the presence of asbestos-bearing rocks that were unexpectedly discovered during tunnelling, work was suspended at the two excavation fronts in autumn 2006, leaving a 105m stretch of tunnel unexcavated. When the asbestos-bearing rock masses were encountered, the tunnel had been excavated from four fronts simultaneously; two starting from the portals and two from the 290m long access adit (figure 1). In order to isolate the asbestos-bearing rock masses from the remaining parts of the tunnel, two confinement barriers were constructed out of HDPE membrane and fixed onto a frame made out of steel tubes and wooden planks. Access to the face has been provided through two decontaminating filters installed on these barriers.

Being the first time that a tunnel had to be excavated in asbestos-bearing rocks in Italy using conventional tunnelling, it was necessary to define an excavation method that would take into account the health of the workers during excavation and muck handling as well as find a site for storing the hazardous muck. Following the evaluation of all possible sites, it was decided to build an underground storage deposit. It is important to note that this will be the first underground deposit of hazardous materials in Italy. Generally speaking, the design of the completion of the Cesana tunnel, though the asbestos-bearing rock, had to take into account three distinct parameters that are closely connected to each other:

- the design of the tunnelling method and



in particular, the support, final lining, and operational sequence to be employed for excavation in the asbestos-bearing rock mass

- the design of the underground storage cavern in which the asbestos-bearing muck will be deposited
- the environmental impact study of the tunnel stretch with asbestos and that of the underground storage cavern

In the following the two last topics are discussed and presented, highlighting the most important design aspects.

Geology

During the project design the excavation of the Cesana tunnel was foreseen to be entirely in the Dolomites of the Chaberton-Grand Hoche formation. The presence of serpentinite rocks was both unexpected and unforeseeable. The mountains slopes are covered by thick and unstable debris and are subject to rock-falls and avalanches, making the construction of roads for exploration rigs unfeasible.

Apart from a limited stretch at the start where the steel-pipe umbrella method was used to cross the debris, drill-and-blast was used in the good quality dolomites. In August 2006 unexpectedly bad rock mass conditions were encountered during the

Above: Fig 1 – The tunnel location plan

excavation, requiring intensive ground reinforcement with fibre-glass grouted elements at the face and around the tunnel. These conditions were due to the tectonic contact between the Chaberton-Grand Hoche dolomites and the calcaschists with "green stones" (ophiolites). The contact between the two units is rarely visible from the surface due to the presence of the debris cover. Both bibliographic and specific studies considered the contact to be located outside the tunnel alignment, dipping subvertically, therefore, only marginally interfering with the excavation. During tunnelling, it was actually discovered that this tectonic contact has a lower dip angle, a total length of 401m and is associated with an intensely fractured rock mass. serpentinitic ophiolitic rock of greenish colour was encountered at the tunnel face at chainage 3+059m. Taking into account the risk associated with the presence of asbestos minerals in such lithotypes, and in accordance with the Piedmont Environmental Protection Agency (ARPA Piemonte), air and rock samples from the tunnel were taken for mineralogical analyses. The analyses conducted on air and rock samples, using an electronic

microscope, a scanner as well as microanalysis of dispersion energy, revealed the presence of tremolite fibres in high concentrations for the valley front (289-55,000mg/kg) and moderate concentrations for the adit front (<100mg/kg). This was therefore classified as a high-risk zone for asbestos contamination. From a geomechanical point of view, the tectonized ophiolitic rock mass is of very poor quality, due to the presence of well developed laminated foliation surfaces.

The need to develop a new design assuming that the remaining 105m would be excavated in an ophiolitic rock mass consisting of green schists of variable concentrations of amphibolite and tremolite became immediate. The new design would need to account for problems related to both the excavation procedure and equipment as well as the disposal of asbestos contaminated material.

Muck treatment and disposal

Three different options were considered for the handling of the excavated material:

- transportation to an existing waste disposal site for dangerous materials
- on site treatment of the muck to transform it into an inert material
- disposal of the muck in an underground deposit that would be built inside the Cesana Tunnel (in a good quality dolomitic rock mass)

The first option was rejected because of the lack of a suitable site at a reasonable distance where the 20,000m³ could be deposited. The second alternative refers to transforming the rock containing asbestos into an inert material using a new thermo-mechanical process developed by the National Research Council of Italy (CNR), which is however in a laboratory development stage. The waste is crushed, mixed with clay, and subjected to very high temperature (650 - 1200°C). A material of ceramic properties without free fibres of asbestos is obtained. This method was also discarded mainly due to the size and location (outside the tunnel) of the plant required. Also, being at an experimental stage, questions were raised about the volume of material that could actually be processed with this method. The best option considering worker safety and works planning, was to construct an underground repository, located in a position along the tunnel where good rock mass conditions had been encountered during tunnelling. Following the choice of the site, it was necessary to define how to store the muck in the underground repository. The first option considered was to simply unload the



Above: Intensely weathered and foliated mica-schists

muck in the cavern. This option was discarded due to the muck exposure to the underground environment during the entire period of the works. The second option was to store the muck in large size bags but this solution was also discarded since the filling of the bags would require breaking up the muck underground with the consequent environmental problems. Placing the bags on top of each other would also be difficult. Finally, it was decided to use pre-cast reinforced concrete 2x1x1m containers which would ensure robustness, easy-handling, long-term durability, increased storing capacity and easy stacking (figure 2). Once filled, inside the contained asbestos contaminated excavation area, the containers will be sealed with a layer of early-strength shotcrete applied at a low pressure and transported to the repository. Up to six containers can be placed one on top of the another (figure 3). Each row will be separated from the previous one by a layer of reinforced concrete. The deposit will have a capacity of about 20,000m³ and can host more than 10,000 concrete containers. The safety equipment, used by workers during the excavation such as masks, overalls, filters, etc., will be stored inside bags that will be placed on top of the last row of containers.

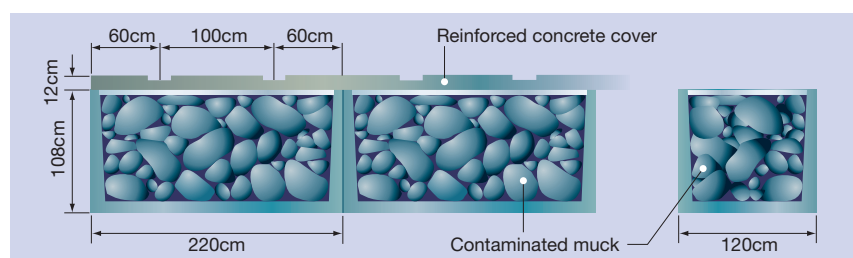
In order to prevent and mitigate the risk of fibre dispersion inside the underground repository during the storing works, an

emergency unit with encapsulating paint will be installed inside the cavern to permit quick operation if some containers should break during handling. Furthermore, a water barrier and an aspiration ventilation system with an air filtering system will be installed at the entrance in order to avoid any fibre dispersion outside the deposit.

Repository construction

The storage cavern section will be 21m wide and 13m high and the underground deposit will be 300m long. Taking into account the very good geomechanical conditions of the rock mass where the deposit will be located, support consists of systematic fully grouted bolts and a 15cm thick shotcrete layer. In order to eliminate any possible contact between underground water and the waste, the cavern will be completely waterproofed with a HDPE membrane that is protected by two layers of TNT. The final lining will be obtained by lattice girders and shotcrete (20-30cm thick) and is designed to ensure the long-term stability of the cavern. The muck storing containers will be placed on a reinforced 50cm thick concrete slab. The Piedmont Environmental Protection Agency requested that the excavation of the cavern shall be proceeded by the construction of an exploration drift. This exploration drift will have a 25m² section and will be excavated by the drill-and-blast method. It will also

Below: Fig 2 - The container for the contaminated muck



contribute to reducing vibrations during the blasting operations of the cavern.

Integrated performance

According to Italian regulations, an integrated analysis of the performance of an underground deposit has to be performed considering the following aspects:

- Geologic evaluation; the deposit will be constructed inside a homogeneous dolomitic rock mass, under an overburden ranging from 250 to 455m. The bedding of the dolomitic formation will be crossed at a steep angle, orthogonally to the cavern axis. No faults or other tectonic structures are foreseen along the deposit
- Geomechanical evaluation; with reference to the Bieniawski classification, the rock mass belongs to classes II and III. Geomechanical observations during tunnel excavation and in-situ and laboratory tests suggest good geomechanical properties both in terms of shear strength and rock deformability.

Additional testing and detailed monitoring during excavation of the exploratory drift will provide a complete geomechanical reference model for the cavern

- Hydrogeological evaluation; as observed from the tunnel excavation and from permeability tests, the rock mass can be considered as completely impervious ($K=2\cdot7\times10^{-7}\text{m/s}$); localized water inflow in fractured zones is expected
- Geochemical evaluation; the rock surrounding the deposit will be dolomite of a very fine grain, a massive structure and an homogeneous texture. This rock mass does not show any sensitivity to chemical dissolution and is not susceptible to karstic phenomena
- Biosphere impact evaluation; the underground location of the deposit and the prevention and mitigation measures adopted in order to avoid any fibre dispersion outside the deposit (encapsulating paint, vacuum ventilation system, water barrier) are sufficient to prevent any impact on the biosphere during the disposal phase). In the long-

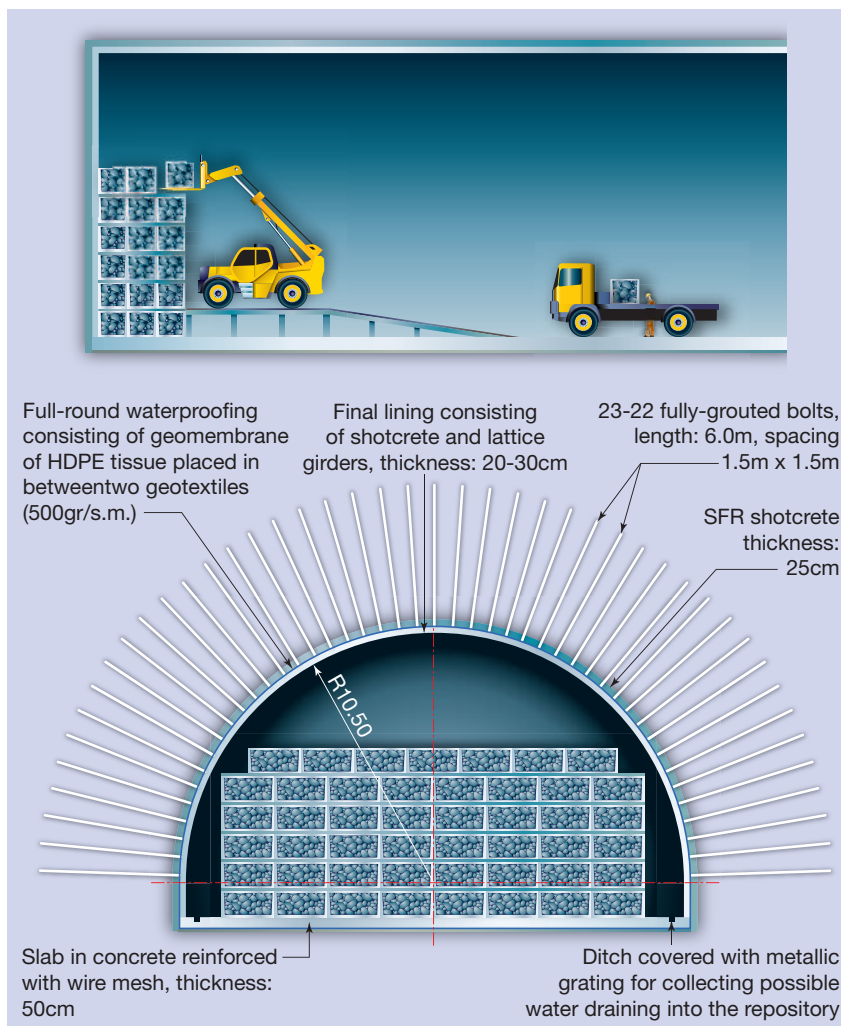
term, the possible impact on the biosphere could only derive from the collapse of the containers which would subsequently lead to a dispersion of fibres inside the deposit and in the water. Despite the very low probability of these events occurring, the deposit will be isolated from the tunnel by a double concrete wall. A drainage system is also foreseen to collect the incidental water infiltration, which will be directed into a shaft equipped with an alert system and pumping facilities

- Operating phase evaluation; the storage operating phase includes transportation of the containers inside the deposit by tracks (3 containers per track). The containers will be put in place by a 60kN capacity forklift which is able to reach a height of 8m. A team of three trained workers equipped with masks (P3 filter) and tyvec overalls is foreseen during storage. The containers will be numbered, marked and registered daily
- Long-term phase evaluation; the stability of the deposit has been evaluated through geomechanical scenario analyses performed by numerical modelling taking into account long-term rock mass and lining properties

In order to obtain the authorisation necessary to operate the designed waste underground deposit, according to National Italian Regulations, the following management plans have been prepared: operational management plan, environmental reclamation plan, post-operational management plan, monitoring & control plan, and financial plan. The first four plans, in practical terms, are similar to instruction manuals for the several activities that have to be performed during the life of the deposit after it has been constructed while the financial plan evaluates the overall costs of construction and management of the deposit. Currently all authorizations have been obtained and construction is expected to start in Summer 2009.

T&T

Below: Fig 3 - The storage area



REFERENCES

1. A Olcese, A Guerini, G Galligani, S Biagioni, G Ciaroni, A Nosetto, C Plisco, M e Bruzzone, S Figini, (2005). Genoa Debottlenecking Project. Quarry and Construction, N. 507, p.1-26.
2. G Seingre, 2006. Management of asbestos on the worksites of the Löetschberg base tunnel. Extended abstract and presentation material. Turin Academy of Sciences.
3. W Chromya, J e Naumannb, Bandmannc 2006. Asbestos in tunnel construction. Tunnelling and Underground Space Technology, Vol. 21, N. 3-4, May-July, p.279-284.



WHEN PERFORMANCE MATTERS...

Why do tunnelling contractors rely on Continental?

They know **Continental** engineers its systems to deliver superior performance in the demanding world of tunnelling.

Take **Continental** tripper booster drives. They add power allowing the conveyor to be lengthened and when strategically placed, they reduce belt tensions at critical points along the conveyor simplifying the design of tight curves common in tunnel projects.

The **Continental High Angle Conveyor (HAC)** system solves many steep angle conveying challenges, up to 90° (vertical) - including tunnel to surface lifts - common to tunnelling.

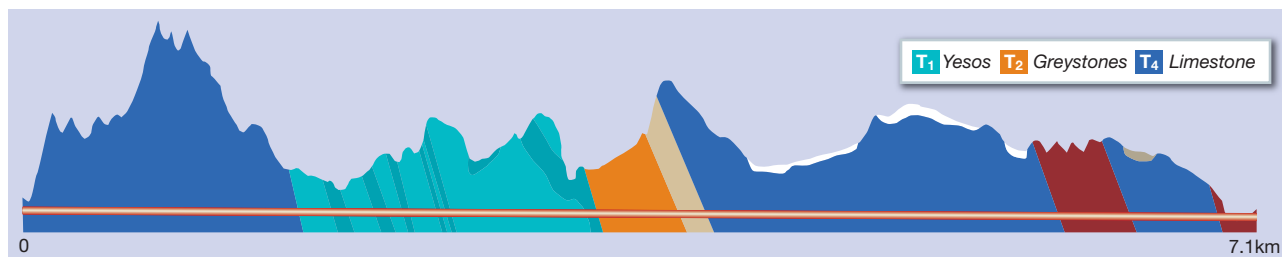
Continental has the know-how and experience to deliver the materials handling solution for your specific application - anywhere in the world.

So, when performance matters, choose
Continental Crushing & Conveying.



CONTINENTAL
CRUSHING & CONVEYING
A Joy Global Inc. Company





Above: Fig 1 - Longitudinal section of the tunnel

Spain's synthetic reinforcement

Rolando Justa Camara and Néstor Moyà i Rubiralta of Acciona describe work on Spain's much needed Oliola water tunnel

Spain is already an arid part of the world, and in early 2008 it experienced its worst drought in 60 years, with the Catalonia region in the northeast one of the hardest hit areas. Up until September 2008 this region had experienced almost no rainfall for 18 months and reservoirs reached only 20 percent of capacity, posing serious threats to its agriculture.

The 84km Segarra - Garrigues canal, of which 42.5km is currently being constructed is planned to both help save water and increase productivity in the region. The canal will service a region of approximately 70,150 hectares and 17,000 farmers and stretch from the Rialb dam in the west to the Albages catchment area in the east. The canal which will have a capacity of 35m³/sec will be made up of a combination of open waterway, aqueducts and tunnels.

Section II of this project was awarded to a Joint Venture of Acciona Infraestructuras and M. y J. Gruas. The US\$39.5M contract is comprised of the 4.8m diameter Oliola water tunnel of which 4,470m was to be a bored tunnel, 521m cut and cover and the remaining 3,000m an open canal.

After the awarding of the contract, the Joint Venture proposed a redesign of the tunnel alignment which increased the length of the tunnel from 4,470m to 7,100m thus negating the need for the open canal. This re-design allowed for the

full optimisation of the TBM drive and in turn significantly reduced the environmental impact on the area which would have resulted from constructing an open canal.

Excavation and primary support

The geology of the tunnel alignment is predominantly sedimentary rock of limestone, greystones and gypsum. Sandstones and limestones account for approximately 4.7km of the bore length with an average RMR 55-60 and 2.3km of massive gypsum with an expected RMR 45-50.

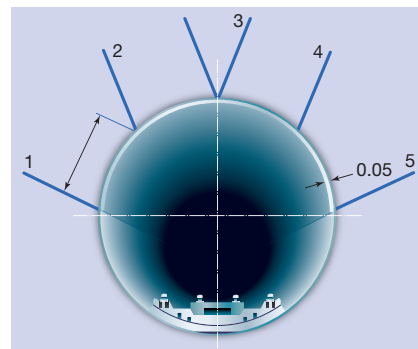
The preconstruction investigation included boreholes approximately every 260m along the proposed tunnel's alignment.

Excavation commenced in May 2008 using a refurbished 5.4m diameter Robbins 182-129-4 TBM owned by Acciona Infraestructuras.

Three types of ground support are specified dependent on ground conditions. These consist of:

- S1 - 4 rock bolts and 50mm shotcrete (upper part) every 1.2m
- S2 - 7 rock bolts and 100mm shotcrete (upper part) every 1.2m
- S3 - Steel arches (THN 16.5kg/m) every 1.2m and 100mm shotcrete all around (except segment)

All shotcrete is macro fibre reinforced with Barchip Shogun synthetic structural fibre. Full site trials were undertaken and the



Above: Fig 2 - Ground support requirements

performance criterion of 700 joules in an EFNARC1 plate test achieved with a dosage of 5kg/m³.

Shotcrete is batched from an onsite batching plant, which will also supply the concrete for the final lining.

As excavation advances a specially designed precast invert segment is placed behind the TBM. The segment is



Above: The formwork for the final lining

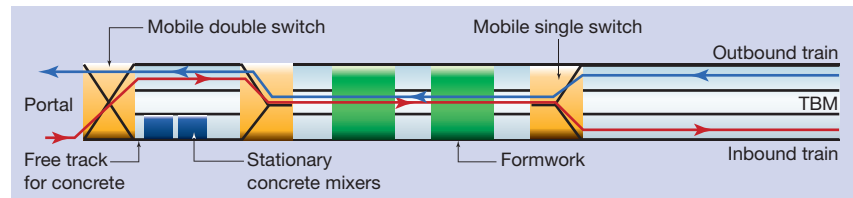
part of the tunnel's final lining and is designed, in terms of loading and configuration, to take the excavation equipment as well as the travelling formwork. The segment is reinforced with a steel cage which has a steel concentration of either 50kg/m³ or 100kg/m³ depending on the ground conditions. Macro-synthetic fibre is used in conjunction with both cage configurations to impart impact and abrasion resistance. Unlike the steel cage, no concrete cover is required for the synthetic fibre, so the full depth of the segment can be reinforced, ensuring that any crack propagation is significantly



Above: Between the primary and secondary lining



The finished tunnel



Above: Fig 3 - The tunnel's switch system

reduced; critical where water may cause corrosion over the life of the asset. The segments are manufactured at a nearby casting yard and transported to site.

Secondary lining

Both the methodology and equipment used for the cast in-situ tunnel lining is critical to ensure that project costs and time remain within the schedule. To achieve this, the secondary lining is to

commence while excavation of the tunnel continues. The obvious disadvantage of only one entry and exit for all materials and muck and the coordination of two major activities make for a challenging environment.

Within one 24-hour cycle the activities of muck removal in order to continue excavation and the setting, pouring and stripping of the formwork are bound to occur simultaneously and cause a bottleneck in the running tunnel.

To overcome this, a specially designed switch system allows for 100m of track to become, in effect, a single track through the centre of the formwork.

This allows the outer rails to carry the formwork. The formwork's frame allows full and empty muck wagons to pass

Macro synthetic fibre reinforcement

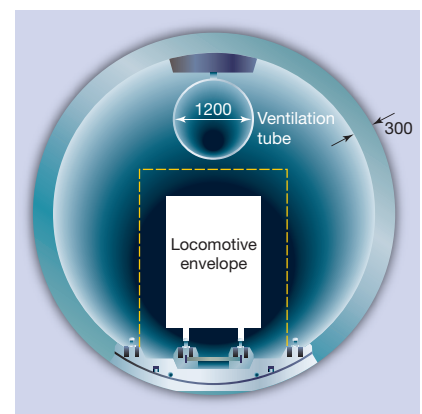
Both the primary and secondary linings and the precast segments use a macro-synthetic fibre, Barchip Shogun, as reinforcement in place of steel fibre and/or WWF.

Macro-synthetic fibres have been used in the construction industry for 15 – 20 years^[2]. However, developments in the last 10 years have enabled their performance to exceed that of steel fibre reinforced concrete on a performance versus cost basis. There are now many examples of major tunnelling projects around the world using macro synthetic fibre for the reinforcing of primary and secondary support^[3].

Andrew Ridout from Elasto-Plastic Concrete (Europe) Ltd explains "There has been a significant move to macro-synthetic fibre in recent years; principally due to the fact that it is a more cost effective, non-corrosive reinforcement, lighter and safer to handle, greatly reduced labour requirement for

installation and with reduced wear on pumping equipment. Additionally, there is a growing amount of evidence showing that macro-synthetic fibre outperforms steel fibre over the longer term^[4]. Durability is also a significant issue for steel fibres. Where concrete does crack, research has shown that steel fibre reinforced concrete loses 45% of its performance within one year at crack widths over 0.1mm^[5]. Macro-synthetic fibre can offer significant long-term durability giving the owner a more durable asset".

Barchip Shogun has been specially developed for shotcrete and concrete reinforcement and is certified to EN BS 14889-26 a mandatory requirement for synthetic fibre in some countries. Barchip Shogun is also fully CE mark registered, in line with mandatory requirements from the European Construction Products Directive, for fibres to be used in concrete.



Above: Fig 4 - Cross section of the final lined tunnel

through its centre. Wagons can be held either side of this single track if required and then dispatched through the formwork when allowed. This process becomes even more important as the distance between the formwork and the portal increases.

The secondary lining has a thickness of 300mm in thickness and the formwork consists of two 15m lengths, each capable of being moved and positioned individually using the outer rails.

Concrete is batched from the onsite batching plant and transported using cigar concrete mixes to be delivered to the concrete pump near the formwork. Originally the secondary lining was designed with two layers of wire welded fabric (150mm x 150mm x 8mm) which has been replaced by 5kgs/m³ Barchip Shogun synthetic fibre. The WWF was specified for crack propagation control purposes. Replacing it with macro fibre significantly reduces cycle times due to the lack of installation time associated with conventional WWF reinforcement.

Additionally, the use of fibre increases safety by eliminating what could be a difficult task. Unlike the WWF, the fibre reinforces the full depth of the concrete, thereby enabling optimum resistant to crack propagation that might occur throughout the concrete structure.

The concrete is Class 30/35 using sulphate resistant cement.

The relatively high slump concrete is able to flow behind the formwork with minimal vibration. Curing times for the in-situ concrete will depend on the distance from the portal to the face, internal and external air temperatures and large seasonal temperature variations. These factors will have a significant bearing on stripping times and therefore cycle times. The expectation is for 30 linear metres per day to be poured allowing 10 – 14 hours for setting, pouring, curing and stripping the form followed by 8 – 10 hours for the concrete pour.

The formwork leaves an aesthetically pleasing finish which is both smooth and fibre free.

Conclusion

The proposed completion of the Segarra - Garrigues canal by 2012 will add much needed irrigation infrastructure to the drought affected region and so ensure the best possible availability of arable land for agriculture.

T&T

REFERENCES

1. EFNARC European Specification for Sprayed Concrete Aldershot 1996
2. Guidance on the use of macro-synthetic fibre reinforced concrete Technical Report 65 The Concrete Society Camberley, 2007
3. A Ridout, 2007. The use of macro-synthetic fibre reinforcement in underground construction, CONCRETE, Vol. 41, No.3, April 2007, pp.39-41
4. E S Bernard, 2008. Embrittlement of fibre reinforced shotcrete, Shotcrete.
5. E S Bernard, 2004. Durability of cracked fibre reinforced shotcrete Shotcrete: More Engineering Developments.
6. EN 14489-1 Fibres for concrete – Part 2 Polymer Fibres- Definitions, Specifications and Conformity



TMS Tunnelscan

Complete tunnel information at a glance

Visit us at:
ITA in Budapest
booth no E16+E17
RETC in Las Vegas
booth no 217

- Visualise. Analyse. Report
- Complete tunnel as-builts at each construction phase
- Significantly reduce construction delays and costs
- Increase overall tunnelling efficiency
- Detailed calculation of quantities

Amberg Technologies AG CH-8105 Regensdorf
Phone +41 44 870 92 22 www.amberg.ch/at



Building new links in Budapest

On 16 March, the second EPBM on Phase 1 of Budapest's Metro Line 4 reached Szent Gellért station, the halfway point on the new link. Eszter Kalman, geotechnical engineer with DBR Metro Project Directory, provides an overview of the line and station construction

Budapest is currently embarking upon its largest transport infrastructure scheme in decades. The US\$2.3bn Metro Line 4 (M4) project will play a vital role in the development of the Hungarian capital's transportation network, linking new terminals in the southwest and northeast via a number of key metro and suburban rail interchanges (figure 1). It is hoped that these new terminals, which are located on the outskirts of the city centre adjacent to commuter motorways, will ease Budapest's significant traffic congestion problems.

Line 4 is being built in two stages by DBR Metro Project Directory, a delivery entity that was established by the City's General Assembly in 2007. The first US\$1.58bn phase of the project, which began in 2006 and is scheduled for completion in 2011, runs from Kelenföldi station on the Buda side of the city to Pest's central Keleti railway terminus. These Phase 1 works have been split into 11 main construction

contracts and include 10 stations and 7.3km of twin 5.2m i.d. running tunnel. The second phase of the line, from Keleti to Bosnyak Ter (Square), will comprise a further 3.2km of twin bore tunnel and four stations. The entire line is scheduled for completion by 2013 and is being financed by the State (79%) and the Municipality of Budapest (21%), with additional support also currently being sought from the EU.

Preliminary design for Line 4 began in 1998 and was conducted by Hungarian firms Förmertv and Uvater in association with the UK's Mott MacDonald. By January 2006, the US\$250M design-build contract for the 7.3km twin TBM driven running tunnels, crosspassages, TBM launch structure, and Gellert Ter station had been awarded to the Bamco consortium, which consists of Vinci Construction, Strabag and Hidépirö Zrt. Contracts for the remainder of the nine stations and associated structures are being built by several other consortiums.

The tunnels are being driven at depths of

15m to 20m through a densely built-up area with many historical buildings, requiring precise monitoring 24hrs a day. Between Gellert and Fovam stations the tunnels will also pass through widely varying soil layers under the River Danube, which is expected to be a major challenge.

Geology

Budapest's geology comprises of Triassic dolomites overlain by tertiary sediments, primarily consisting of homogenous clayey sandstones and marls, followed by cohesionless quaternary deposits from the old Danube floodplains. The soil conditions along the tunnel alignment can be divided into three distinct zones:

On the Buda side of the city, between the Kelenföldi Terminus and Gellert Square, the tunnel mainly lies in over-consolidated Kiscelli clay (Middle Oligocene), similar to London Clay. The depth of the Kiscelli clay varies, but it thins sharply towards Gellert Square, giving way to the Tardi clay formation (Lower Oligocene).

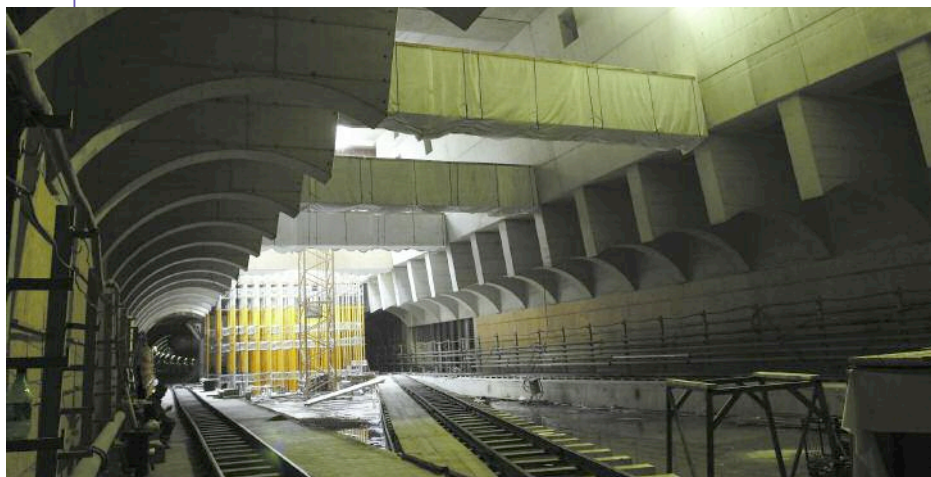
Between Gellert and Fovam stations is the most challenging zone of the alignment, a major fault zone under the Danube river, where ground is expected to be very poor.

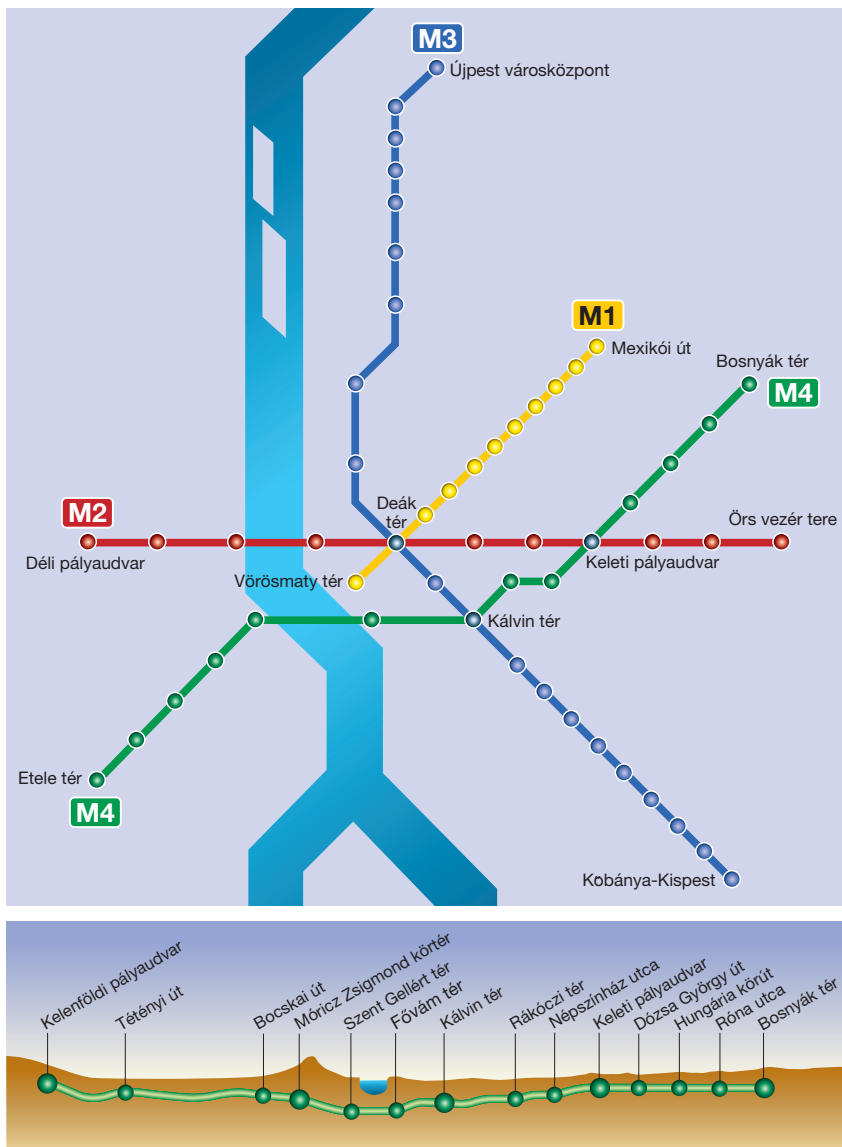
On the Pest side, between Fovam Square and Keleti Railway Terminus, the geology becomes increasingly younger (from Middle to Upper Moicene) and highly changeable - varying locally from soft clays to sand, fine sand and sandy gravel. Throughout the route the groundwater level is located above the tunnel in the quaternary deposits.

TBM tunnelling

Due to the major differences between the ground conditions on Buda and Pest sides of the city, two hydraulic Herrenknecht EPBMs with monoblock cutterheads were selected to drive the running tunnels. These machines have been operating in open and compressed air modes through the Kiscelli clay on the Buda side. Each have been progressing at an average rate of about 12 rings (18m) per day, working 24hrs a day, six days per week, and both have now reached Gellert Station where maintenance works are being undertaken before

Below: Works underway at Móricz Zsigmond Square Station following TBM passage





relaunch under the Danube. From here they will run in closed mode for the majority of the remaining distance to Keleti. In this poorer geology careful control of the machines will be key to the success of the drives.

Just-in-time delivery of the five segment plus key pre-cast concrete lining rings for the project is being provided by Slovakian-based manufacturer ZIPP. The rings are lowered into the tunnels by two heavy-duty cranes and transported, along with mortar, via railbound trains. Each train also includes four muck wagons, which are also lifted by crane and unloaded into a dedicated spoil area. With both TBMs working, around 135 trucks are required daily to transport the waste to its final discharge site 20km away.

From an environmental point of view, one of the most sensitive aspects of the M4 works is the tunnel section under the Danube and Szent Gellért square station.

Prior to construction this area was subject to thorough geological and hydrological testing in order to develop a construction methodology that would preserve the city's famous underground thermal springs. During construction, a continuous groundwater monitoring system was established at Szent Gellért square, which comprised 20 wells to measure the quality, temperature, composition and rates of discharge into the springs.

Stations

The stations are being built by numerous open pit, top-down and mixed construction methods. Mórícz Zsigmond Square Station is an open-pit station. Support of the pit is constructed in two stages, from surface level to a depth of 5-7m a secant pile wall is

Right: Construction of the internal walls at Bocskai Road Station

Left: Fig 1 - Map of Budapest's Metro network and long section of Line 4

installed, followed by 27m deep x 1m wide diaphragm wall. Following excavation, a 3m thick reinforced concrete base slab is formed. The main structure of the Mórícz Zsigmond square station has now been built and both TBMs have already passed through the station.

The stations built by the top-down or 'Milanese' method are the Tetenyi road, Bocskai road, Nepszínház and Keleti Railway Terminus stations. Here the top slab is constructed first, then mining is continued underneath the slab.

During construction of Tetenyi road station engineers paid special attention to the preservation of "Bikás Park". Once the work is finished the area will be reinstated. An interesting feature of this particular station is a glass dome that will be built over the station, through which sunlight will reach platform level. The Tetenyi station shaft, diaphragm walls, base slab and also the floor slab over the passenger area are all now completed.

The commercial and administrative centre of Bocskai road is a shopping precinct, which will greatly benefit from the addition of the metro. One of the most important aspects of the station design here was the need to facilitate the need for future branch-lines towards Budafok. The ventilation shaft, the mining ventilation tunnel, the diaphragm walls and the floors have all been completed. Both TBMs have now passed these two stations and as a consequence construction of the internal walls is now well underway.

On the Pest side of the city, Nepszínház road station and the Keleti Railway Terminus have been built by cut and cover. Nepszínház road station is 108m long and 19.6m deep. The station box has now been completed by the contractor, but the ventilation shaft and tunnel is yet to be constructed. Keleti Railway Terminus will be





Above: Open cut station construction works underway at Bocskai road station and Keleti main railway terminus

the final station on the first section of the M4 line. It is one of the largest stations at 86m long and has a turn-out structure which is a further 100m in length. The construction methods are mixed, with an open cut station box and cut and cover turn-out structure.

The M4 Kelenföldi Terminus is located directly below the mainline railway station, providing easy access between rail, metro and local transport modes. Construction has therefore been required under the 28 tracks of the terminus above. Divided into five sections, in total the works will take two years to complete, with the last of the five sections currently underway. The method used is diaphragm walls with cut and cover but, as this station is the final station on the line, there will also be an 80m long NATM interchange tunnel, which has a cross section of more than 120m². Constant monitoring of instrumentation is essential during the excavation.

Gellert square station is possibly the most difficult of the tasks that had to be solved by designers and contractors. In addition to the thermal springs, which supply the city's famous Gellert Spa, the Budapest University of Technology and a prestigious hotel are also nearby. There are also numerous residential properties in, and adjacent to, the square. The station was designed to allow passengers to connect easily with surface transportation services as well as the neighbouring University.

Following construction of the 41m deep diaphragm walls, an open construction pit was built at the end of 2007 for the upper station box. NATM works for the remainder of the station, including platform tunnels, then advanced from a 31m deep shaft next to one of the University buildings. Currently, a sprayed concrete lined (SCL) crossover structure is also being built, by enlarging the segmentally lined TBM-bored running tunnels. As part of a design review for Bamco to confirm the feasibility of the crossover design in the over-consolidated Kiscelli clay, Mott MacDonald carried out

extensive numerical modelling and ground movement analyses for the area affected by the tunnel and crossover construction. Building response assessments were also performed for the structures in the station vicinity identified at risk by the contractor. In particular, Bamco has taken great care with the thermal springs, which are considered a national treasure. Having both now reached Gellert square station, the TBMs will be reset from open to EPB mode before relaunching them on their drives under the River Danube.

Fovam square station is the first station on the Pest side of the river. The exit to the station is adjacent to the Corvinus University and links with the surface tram transportation network. This area will be fully rehabilitated parallel to the metro station construction.

This is one of the deepest stations located 46m underground. It is particularly challenging as half of the platforms will be located under the banks of the river. Therefore these are being built by NATM using ground freezing technology. This mining work carries the highest risk factor on the whole line. The geological conditions are very changeable at Fovam square. One of the highest risks results from the tectonic fault zone, which runs along the west side of the station under the Danube. By contrast, the eastern side of the station is located in sandy rock, sandy silt and sand.

The contractor is using a large array of geotechnical instruments to monitor the excavation and prevent against collapse. Piesometers, horizontal inclinometers, reverse head (RH) horizontal extensometers, convergence measuring points and vertical inclinometers are all being employed. In addition, a Gyro Smart borehole survey system for 3D analysis of the freezing pipes and temperature lances have been installed.

At Fovam square station on the upper station level, grouting works will be finished by the middle of this year. The platform tunnels under the Danube are due to be

finished by April and under the University by May. Therefore the first TBM is scheduled to arrive at the station by early May and the second early June.

Rakoczi square station will have an exit on the surface that will take up the smallest amount of space as possible, additionally passengers can reach the market hall by large rapid elevators. With regard to the station works, the station box and ventilation shaft have been built by open-pit. Following this the contractor finished the ventilation tunnel and the platform tunnels by NATM. During platform tunnel construction the pore water pressure must be reduced, as the soil conditions here are possibly some of the poorest on the line. The soil consists of sand, sandy silt and silt; there are also two separate groundwater levels under the surface.

Kalvin square station will be the main interchange between Metro Line 4 and Metro Line 3. As part of the new works the station's existing underpass system will be completely rebuilt. As a result of this new interchange, a high-standard public transport link will develop between South-Buda and North-Pest as well as South-Pest. An interesting point of this station is that the M4 tunnels will run above the M3 tunnels. Another sensitive point of these works is the close vicinity of the surrounding buildings and that one of the busiest intersections in the city will have to be closed for months. The construction works here will be finished soon.

Overall on the project, one of the biggest challenges at present is the management of contractor claims, with a team of international advisors currently assisting the Project Directorate and Contractors to resolve disputes. Over the coming months however the biggest challenges will be the River Danube TBM crossing and completion of the ground freezing operations at Fovam square station.

Currently 40% of all the works on the first phase of the M4 have been constructed with completion expected in 2011. T&T



Not all rebuilds are created equal



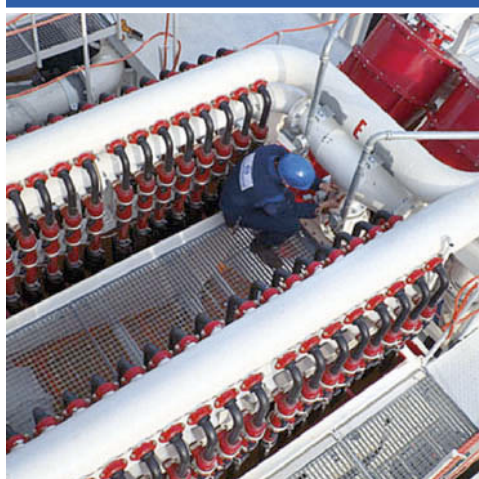
Rolling Stock
Scooptrams
Drill Jumbos
Mine Hoists
Stage Winches
Ventilation Equipment

Locomotives



Phone: (970) 259-0412 | Fax: (970) 259-5149 | www.miningequipmentltd.com

Your Reliable Partner in Tunnelling Separation Technology Equipment Worldwide



Exhibitor at ITAWTC Budapest May 23-28, 2009



Schaenburg MAB GmbH • Weseler Str. 35 • 45478 Mülheim a. d. Ruhr / Germany
website: www.schaenburg-mab.com • e-mail: hwm@hwm-engineering.de
phone: +49 (0)208 - 9991 - 0 • fax: +49 (0)208 - 59 24 09

SCHAENBURG MAB



Marti Technik belt conveys rock in hilly Hong Kong

The Castle Peak cable tunnel in Hong Kong aims to improving the supply security to the existing network in Tuen Mun, Yuen Long and the Lantau airport. It is bored through the mountainous area of the 583 m high Castle Peak. The tunnel is approximately 4.5 km long with a 4.5 m internal diameter to contain eight 132 kV cable circuits.

The solid geology of the tunnel alignment consists predominantly of Tsing Shan granite and Tuen Mun formation (faulted, folded and metamorphosed sediments and lavas, outcrops in the foothills and lower-lying ground at the eastern part of the alignment).

Marti Technik has been entrusted with the design, production, on-site assembly and commissioning of the entire 4,650 m conveyor belt system, including heavy-duty 400 kW electrical supply and a fully automatic control of the rock material flow from the tunnel boring machine to the final disposal site. An operator monitors the conveyor belt system on computer screens. The belt is designed to carry a flow rate of 370 t/h (total quantity of 300,000 t), with a driving power of 400 kW.

Marti Technik AG Lochackerweg 2 CH-3302 Moosseedorf

Tel. +41 31 858 33 88 Fax +41 31 858 33 89 info@martitechnik.ch www.martitechnik.ch

JOINT VENTURE TUNNEL ACHRAIN



Beton- und Monierbau Gesellschaft m.b.H.

Address Bernhard-Höfel-Str. 11
A-6020 Innsbruck, AUSTRIA
Telephone +43 (0) 512 / 33 11 - 0
Fax +43 (0) 512 / 39 26 55
E-Mail office@BeMo.co.at
URL www.BeMo.net



Jäger Bau GmbH

Address Batloggstr. 95
A-6780 Schruns, AUSTRIA
Telephone +43 (0) 5556 / 71 81 - 0
Fax +43 (0) 5556 / 71 81 - 818
E-Mail office@jaegerbau.com
URL www.jaegerbau.com



ALPINE Bau GmbH

Address Alte Bundesstr. 10
A-5071 Wals bei Salzburg, AUSTRIA
Telephone +43 (0) 662 / 85 82 - 0
Fax +43 (0) 512 / 85 82 - 9900
E-Mail office@alpine.at
URL www.alpine.at



Risk. It's the hurdle you need to clear to earn the results and rewards of underground infrastructure, and no one manages your risk better than Black & Veatch. Our innovative "spiral" process continually re-evaluates and responds to shifting risk variables. Whether it's a massive rehabilitation project in Hong Kong, or a pacesetter tunnel in Milwaukee, no one moves water like Black & Veatch.

weknowwater@bv.com
www.bv.com



BLACK & VEATCH
Building a world of difference.

Products

Secrets of Cumbria

SM Pelorus has completed Ground Penetration Radar (GPR) work valued at US\$14,700 to analyse the buried structure of Thirlmere Aqueduct, Cumbria, the 134km long Victorian water pipe connecting the Lake District to Manchester.

The radar work, which took place hundreds of feet below the Dunmail Raise pass, was designed to help United Utilities understand how the tunnel was constructed. United Utilities is the regional water company for the north west of England and invests millions of dollars every year to ensure the reliability of water supplies to its seven million water customers.

By looking at the thickness and quality of the concrete lining SM Pelorus were able to gather enough data to interpret if there were any voids or potential weaknesses from within the pipe over a few of its sections.

Associate Director for SM Pelorus, Mike Wilson said, "To meet some challenging operational conditions our engineers were required to complete 'confined spaces training' to help them fully understand the safety issues associated with working underground and in wet conditions as the water ingress in the aqueduct was very high."

John Butcher, United Utilities'

operations manager, said that although they were unable to substantiate the legend that a 10th century king was buried under the cairn at Dunmail Raise, the radar had shed light on another local mystery. He said: "Legend has it that two tunnelling teams met spot on in the centre of the mountain. Actually, it looks like they were probably about 8ins out. It's still impressive given the technology they had available at the time."

The radar analysis is the latest stage in a six-year, US\$17.6M overhaul of the pipeline which requires the aqueduct to be drained. It is the fourth time United Utilities has closed part of the



aqueduct, and after two years of inspection engineers have begun to make repairs.

This section of pipeline was fully operational again by mid-December.

S M Pelorus

Web: www.soil-mechanics.com

Lining for tough locations



Trenchless contractor, Perco, has added portable UV-curing to its EcoCIPP cured-in-place-pipe lining fleet. The compact system enables relining of sewers and culverted watercourses in difficult terrain and access conditions.

Perco's portable 'Bluetec' UV rigs can be easily moved on tracked, all-terrain vehicles and handling equipment. This offers an operating solution for narrow access situations and rough ground, that have previously either entailed extra cost to create access, or prevented relining altogether. As a result, culverts under railways, roads, rivers and

canals are among the applications set to benefit. Bluetec uses the same Brandenburger technology as Perco's established EcoCIPP lining system. Installed GRP liners therefore possess the same outstanding characteristics of flexural strength, elasticity and water tightness.

The Bluetec portable system has enhanced light sources and control, with online monitoring and documentation of the full curing process. Using the portable equipment, Perco engineers can reline lengths of up to 250m per run. The system handles internal diameters of 250mm to 1200mm, while circular, egg-shaped and special profiles may be relined.

Perco Engineering Services

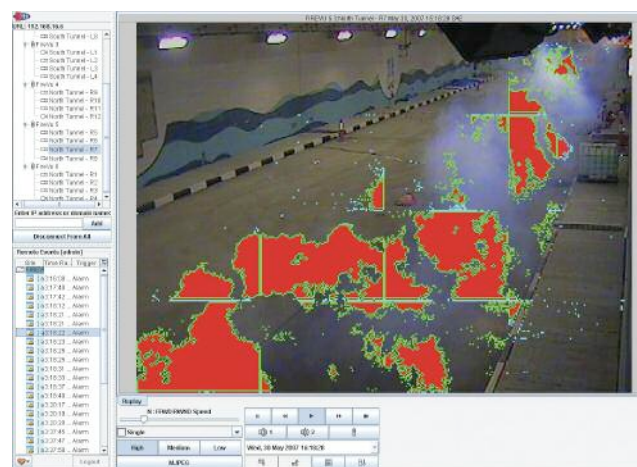
Web: www.perco.co.uk

Fire award finalist

D-Tec, part of AD Group - and a world leader in CCTV camera-based Video Smoke Detection (VSD) - announces that it is a finalist in the prestigious Fire Excellence Awards, run in conjunction with the International Firex and Fire & Rescue exhibitions.

The company has been shortlisted in the key Export Innovation category for its successful deployment of VSD, which analyses images to provide an early warning of fire, in a growing number of tunnel projects worldwide. Applications of note undertaken by D-Tec and highlighted in its award submission include: Italian road tunnels and the Sydney Harbour Tunnel.

Said Ian Moore, Managing Director of D-Tec: "We are very pleased to have reached the final stage of the Fire Excellence Awards for our global tunnel projects. The confined nature of tunnels presents a uniquely challenging environment where fire safety is concerned. Factors such as the length of tunnels, the difficulty of access, and the higher heat release rate from fire, make any delay even more critical than in other scenarios. As a result, at D-Tec, we are seeing growing interest in the deployment of Video Smoke Detection with its proven ability to identify smoke rapidly (typically in seconds). There is also the added flexibility which comes with the availability of IP based solutions



such as FireVu."

The winners of the prestigious Fire Excellence Awards will be announced at a ceremony on the

evening of Tuesday 12 May at the Hilton Birmingham Metropole.

D-Tec

Web: www.dtec-fire.com

Inflatable packers

for hydrogeological investigations
and civil/underground engineering



Sava-Solexperts Inflatable Packers are designed for any number of applications in boreholes or water wells. They are used whenever a borehole or well has to be sealed while at the same time guaranteeing access to the isolated borehole section.

Competitive Advantages

Performances:

- high inflation pressures
- large inflation diameters
- big mandrel diameters
- long durability

Abilities:

- single-, double- and multi-packer systems
- each packer individually made
- custom made packers
- application services



SAVATECH d.o.o.
Industrial Rubber Products and Tyres
Environmental Protection Products

Škofjeloška c. 6, 4502 Kranj, Slovenia
T: + 386 (4) 206 63 88
F: + 386 (4) 206 63 90
www.savatech.com

Being PAID PEANUTS?

visit the recruitment section at
www.tunnelsonline.info



www.hbi.ch

We are internationally recognised consultants in

- **Tunnel Ventilation**
- **Emissions and Air-Quality Modelling**
- **Aerodynamics and Thermodynamics of Tunnel Networks**
- **Escape Route Planning**
- **Tunnel Equipment**

Our services focus on:

- Road, Railway and Subway Tunnels
- Consulting, Studies and Design Checks
- Design, Planning and Commissioning
- Site Supervision and Measurements
- Acceptance and Fire Tests

We are at your disposition for small and large assignments at any stage of the design and implementation process.



«More than 500 Tunnel Ventilation Systems Worldwide Since 1963»

HBI HAERTER LTD. CONSULTING ENGINEERS

Stockerstrasse 12 CH-8002 Zurich Switzerland
Tel. + 41 (0)44 289 39 00 E-Mail: info.zh@hbi.ch
Fax + 41 (0)44 289 39 99 Web: www.hbi.ch
Switzerland: Zurich, Berne / Germany: Heidenheim

Mine stabilisation beneath Hatfield

The Briars Lane area of Hatfield is close to the town centre and consists of housing, playing fields, and a school. Upper Chalk lies approximately 5 to 10m below the surface, and it is this that attracted miners in the 19th and early 20th Century. In the process of extracting the rock, a network of shafts and narrow adits were formed. Chalk mining ceased around 1920, with most mines abandoned, and very few records left.

Hatfield, some 20 miles north of London, expanded in the mid 20th Century, and from 1937 the Briars Lane area was developed for housing. No attention was paid to the mines beneath until, in 1978, the first major subsidence event occurred with a plan area of 4.6m by 3.6m. A second event in 2001 resulted in a 6m deep hole with the collapse of a footpath and some property damage.

Project Manager Mace and Designer and Contract Supervisor Hyder were brought in by Welwyn Hatfield Borough Council in Partnership with Hertfordshire County Council in 2005. The resulting risk assessment required the evacuation of a number of at risk properties and the closure of the school. This suddenly gave the project a very high public and political profile, and the team had to move rapidly.

The joint British Tunnelling Society and Min-South meeting of February 2009 saw a presentation on the stabilisation of old mine workings beneath the Briars Lane area of Hatfield, Hertfordshire, UK, by Chris Milne a geotechnical consultant to Hyder Consulting, Andrew O'Donovan of BAM Ritchies, and John Rigby-Jones of RJM Ground Solutions Ltd.

Scheme development

The scheme objectives were to allow safe occupancy of the site, to ensure minimal future movement from the mine workings, and to restore public confidence. At the same time the works had to be carried out with a minimum of disruption to residents, and within budget and programme.

Between March and July 2005 a ground investigation programme was carried out, which defined the core site as an area of around 3 hectares. A feasibility study from September to December defined the scope of the proposed works, and a risk assessment in November 2005 resulted in the evacuation of a number of properties. In December 2005, a successful application for funding from English Partnerships was made. Site works were carried out between

August 2007 and March 2008, and the properties re-occupied in June 2008.

A desk study and public consultation process revealed a history of ground movement dating back to the original development, and evidence of a complex network of galleries beneath the site. The chalk had been extracted, fired to form lime and then spread on fields to reduce acidity and promote growth, and an old map of the area showed a kiln present. Certain horizons of chalk are especially pure and it is likely that the miners followed these, identified by colour and softness.

In the development of a solution, there were a number of key risks which included the efficacy of the treatment, the effects on the adjacent properties, maintaining stakeholder and public confidence, and the unknown numbers, locations, and volumes of the voids. In an enlightened move, the Client retained responsibility for these risks, allowing the integrated project team to manage these whilst concentrating on developing and implementing the best technical solution. A joint risk register was produced and maintained throughout the project, and this placed significant emphasis on obtaining high quality data, controls during the implementation phase, and a comprehensive validation exercise.

Site investigation

The first challenge for the team was to ascertain the extent of the workings and their volume. 82 boreholes were drilled, and surveyed using down-the-hole laser, microgravity and CCTV. A further 1581 dynamic probes were driven to typical depths of 20m providing a record of



Dynamic probe rigs in action

penetration resistance against depth.

Investigations showed that there were up to 4 levels of workings between 6m and 20m deep, each typically 2m wide and 2 to 3.5m high, but these were of varying width and irregular orientation, and were often partially or wholly blocked from collapsed material, leaving disturbed ground above.

Procurement

An Engineer's Design was developed employing foam concrete backfill of workings and compaction grouting of voids. It was appreciated that the need for design modification and treatment methodology refinement would be necessary during the treatment works to respond to variations in ground conditions and the extent of the workings encountered. Consequently a high quality data management system was demanded of Contractors to allow real time monitoring of the efficacy of the treatment works and extent of treatment. In order to allow realistic validation of the treatment a range validation criteria were set including additional dynamic probing.

The emphasis on quality was highlighted to prospective Contractors throughout the tender process, and tenderers were marked on a 90% quality assessment of technical and risk management abilities, with integrated working within a true partnership key, and only 10% on price. This led to the appointment of BAM Ritchies as Main Contractor on an NEC Option B Contract, with RJM Ground Solutions as their technical advisors.

Public interface

Keeping the public informed and minimising disturbance were key scheme objectives. Regular meetings with residents groups



Vertical bulk filling holes being drilled

were arranged, and information was passed on through regular letter drops. Sites were erected and dismantled daily, and the batching plant was provided with shielding.

Building condition surveys were carried out on all properties and an extensive monitoring system installed, consisting of continuous remote monitored tilt meters and precise levelling surveying during treatment works. Data was continuously logged and had trigger levels been exceeded, texts would be sent to key personnel. This system was tested, but no trigger values were exceeded during the works.

Void filling

Some 675 vertical and 120 inclined holes were drilled for the bulk filling exercise, typically 20m and 35m long respectively. A variety of rigs were used including small manoeuvrable tracked rigs, and larger excavator mounted drilling booms for reaching over hedges and fences, always aiming to minimise disturbance. The project included a contingency for drilling from

within houses and the necessary reinstatement, but the need for this was successfully avoided using inclined drilling.

All holes were surveyed using a standard drainage CCTV system, and those indicating voids were re-surveyed using a directional CCTV, which helped to define the void shape and location, though volumes were very difficult to estimate. All holes that had intersected substantial voids were then filled with a foamed concrete with a density of 0.5t/m^3 . A total of 2240m^3 was injected, with two holes taking 300 and 350m^3 each.

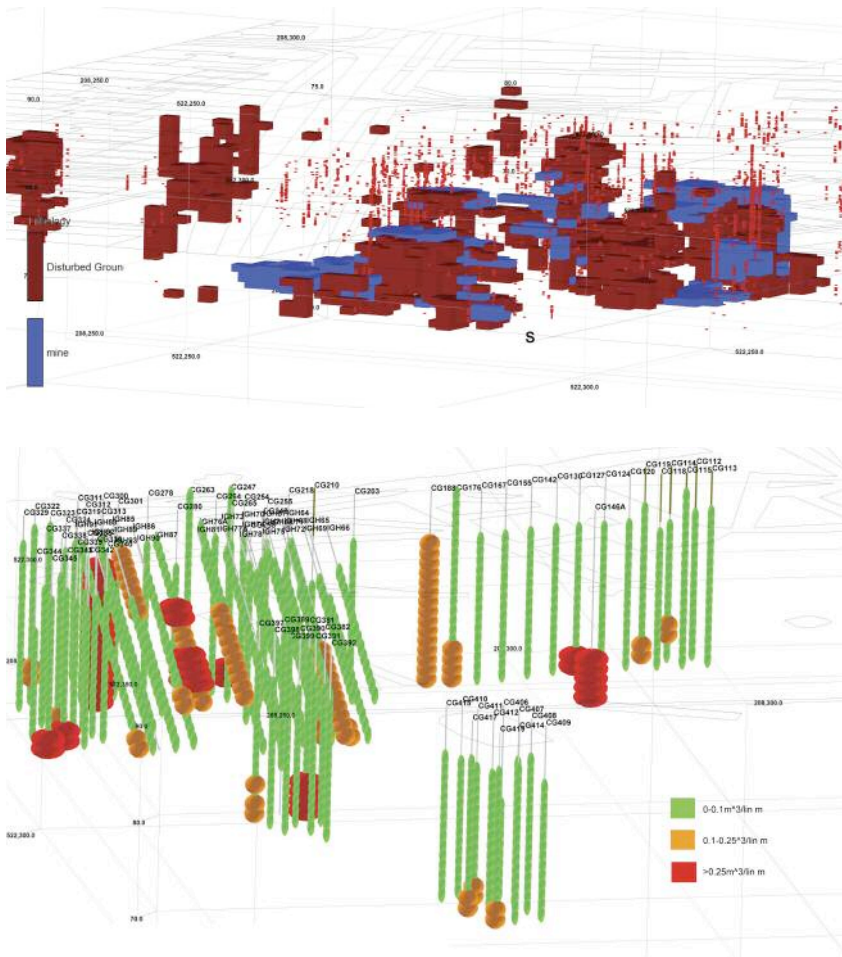
Compaction grouting

With the larger voids filled, a comprehensive exercise of compaction grouting was employed to fill any remaining voids and consolidate and strengthen zones of disturbed chalk. There was a nearby drinking water extraction point from the chalk aquifer, and the Environment Agency would not allow the use of PFA within the grout mix. To maintain pumpability, a replacement bulk filler was required, and the team successfully carried out off-site trials of a low slump mortar mix using limestone dust. However, the short material life of this mix combined with the high head losses experienced during initial site use demonstrated the need for a more pumpable thinner grout with a longer life, and the team quickly developed this. The final 8:1 mix (limestone dust:cement) developed approximately $1\text{ to }2\text{N/mm}^2$ at 28 days, and a total of 1920m^3 was injected during the project.

Inflatable packers were employed to inject in typically 2m stages in each hole, with injection pressures of 10 bar targeted below 10m reducing to 5 bar between depths of 5-10m. Injection pressure was measured immediately adjacent to the top of the hole, along with an accurate volume measurement that was subsequently reconciled against batching records. The



Batching plant shielding



Left: Fig 1 - 3D model from dynamic probe data

Below left: Fig 2 - Compaction grouting data

The Rockworks output also formed a key part of the multi point validation process allowing areas requiring more treatment to be identified. A few locations required minor retreatment, but the majority showed that first stage filling had been totally successful.

Validation reports were produced summarising data from drilling, void filling, grouting, and the validation probing exercises to demonstrate that the residual risk of voids was extremely low. To enable early re-occupancy of site, a total of 28 sectional reports were produced.

Conclusions

The team put the success of the project down to the early acceptance that change is inevitable and must be managed by the whole team working together in a framework of constructive cooperation. Real-time data management enabled the assessment of treatment efficacy, allowed informed modifications to be made to the treatment methodology and permitted validation to be carried out during the treatment process. Above all, mine treatment schemes like Briar Lane are about confidence, and this can only be achieved by a high quality product.

T&T

team suspected that two early instances of packer failure were due to high injection pressures forcing grout around the packer. Subtle modifications to the injection procedure and the switch in mix design prevented reoccurrence. To ensure maximum plant mobility and minimum disturbance, the injection pumps were fitted to site dumpers, running from the vehicle hydraulics. As part of the validation process a further 251 dynamic probes were undertaken.

Validation

From the outset, it was clear that the management of data was a major exercise with over 375,000 dynamic probe data points along with dozens of ground investigation logs and many hours of CCTV footage. To deal with this challenge the Rockworks 3D mine modelling software package was selected, and the use of this from the outset allowed the team to address the inevitable uncertainty by permitting (figure 1): Continuous review of progress; real time discussion on the efficacy of the treatment and the need for additional work; sectional validation of the works (and hence site re-occupancy).

Dynamic probe data was entered into the model with greater than 5 blows defined as intact chalk, 3-4 blows as disturbed chalk, and 0-2 blows as a void. Figure 1 shows the mine model developed from the pre-treatment data with voids and disturbed chalk shown red and intact chalk shown

blue. Bulk filling volumes and grouting volumes per injection stage (figure 2) were fed into the model as these took place, resulting in a continuously updated model of the remaining disturbed ground. This allowed the team to assess the treatment carried out so far on a weekly basis, and to target the next stage to maximum effect.

QUESTIONS FROM THE FLOOR

Alan Webster of the IMMM asked what level of monitoring is continuing following project completion.

Monitoring of the treated area forms a part of an on-going wider study for the Hatfield area (which includes items such as emergency planning), and the team are very confident that the residual risk from further ground movement in the treated area is negligible.

Dr Ponnampalam Linkeshwara of Network Rail asked how many properties the work covered and what the cost of the works were per property protected.

The project covered approximately 100 houses and with a total budget of US\$5.8M, the cost per property was therefore around US\$58,444.

In a supplementary question, Dr Linkeshwara asked what lessons were learnt and what would be done differently were the project to be repeated.

Two main points were raised: The lack of

confidence in attaining the required fill using a stiff mortar grout mix as recommended by the CIRIA grouting guidance and the uncertainty in assessing this pressure at the point of injection when measured at the ground surface when high head losses are occurring along the injection line.

David Hartwell, Consultant asked whether there was any evidence of heave or local fracturing into permeable zones.

The injection pressures were chosen so as to avoid ground heave, and the upper 5m of ground were not treated except where open voids were noted. Due to these controls, no significant heave was noted. Two injection packers were lost during initial grouting works, but the team consider that this was due to high injection pressures causing ground movements and grout flow around the packers. This did not re-occur following the change in grout mix and injection procedure.

Rapporteur: Ken Spiby

Finne Tunnel's segment production

As a part of the north-south rail connection between Berlin - Munich - Verona, the German national railway company Deutsche Bahn AG is pursuing the expansion of the Berlin - Leipzig/Halle - Erfurt - Ebensfeld - Nuremberg railway line.



Above: The Finne Tunnel segment yard and portal

Section VDE 8.2 on Germany's Berlin to Verona Rail Link comprises the construction of a 123km new line from Erfurt to Leipzig/Halle. The heart of this line, which also includes several large viaducts and 2 other tunnels (the 6,414m long Bibra Tunnel and the 2,072m long Osterberg Tunnel), is the 6.8km long Finne Tunnel.

The Finne Tunnel Project envisages the construction of two single-track TBM driven tunnel tubes, each 6,822m in length.

In December 2006, the Finne Tunnel JV, consisting of the companies Wayss & Freytag Ingenieurbau AG, Max Bögl and PORR, was awarded the contract. Due to the very high requirements concerning the precast units and the tight schedule, the JV decided to erect a segment production factory on site.

The company Mobilbaustoffe was commissioned to produce the segments and the contract for the production of the reinforcement cages was awarded to the Ruhl company in September 2007.

For the organisation and coordination on site the JV appointed Mr. Adi Hagelüken, Wayss & Freytag, as project manager and Mr. Baumgartner, Porr, as project coordinator in August 2007. The aim was to erect the complete on-site factory within 7 months.

Concept

In all, 8 sets of moulds are used in the stationary production, producing a maximum of 2 segments a day each. The 48m wide, 112m long segment production building also accommodates the temporary store, next to the production line and is divided into 2 sections, each of which is equipped with two gantry cranes. The building is insulated and provided with a heating system to guard against the low temperatures that may occur in winter. The finished segment leaves the building via the temporary store from where it is transported to the open-air storage yard using flat bed trailers.

As it was possible to build the open-air storage yard in the immediate vicinity of the production site, it can be quickly reached. The open-air storage yard has a max. storage capacity of 825 rings. This is equivalent to a stock for approx. 1.5 months if both TBMs are running concurrently. The open-air storage yard is served by

two portal cranes, each of which can lift 20 tonnes. Thus, each is capable of lifting one segment. In the storage yard, the segments are loaded on to the tunnel drive locomotives and transported to their final point of installation.

The production of the reinforcement cages takes place in a separate building in parallel to the segment production. This building has an area of approx. 2,000m². Both bar steel and roller steel are used for the production of these cages with the steel supplied stored inside the building. All individual components of the cages are produced on site and assembled by 8 teams to form the final cages.

The cages are stored outdoors in an area from where they can be supplied quickly to the segment production. The concrete is produced on site in a mixing plant specifically erected for this purpose.

Construction progress

In August 2007, all necessary requests for quotations were issued. In mid-November, the last contracts were awarded. Earthworks started in mid-September and were completed two months later. The existing soil had to be replaced or improved using lime to a depth of 2m.

Simultaneously, the construction of the segment and reinforcement production buildings started. In early 2008, the installation of equipment in the segment production building commenced. The first sets of moulds were supplied and assembled as early as January. The reinforcement production building was fitted out in late January. Thanks to the mild winter, it was also possible to complete the asphaltting work necessary on the site area in February. While the earthworks were still underway, the two portal cranes were delivered in February and erected in one month. By the beginning of March 2008 all the equipment was on site with the exception of 2 sets of moulds. The trial run started in March with the target production rate of 8 rings per day achieved in May.

Design

The two tunnel tubes to be driven have an i.d. of 9.60m. The segments are 0.45m thick and 2m wide in a 6 + 1 ring.

The segments are provided with anchor rails, which are used to fasten the overhead contact lines in the tunnel. The sealing gasket was specifically developed for the Finne Tunnel by the company Phoenix. It can withstand a testing pressure of 12.1 bar. For grouting the annular joint an additional grouting hose was installed in the segment. Since each tunnel tube will be exposed to high concentrations of sulphate over a length of 200m, cement with a high sulphate resistance was added as a precaution during the production of a total of 200 rings.

Summary

The JV and its partners succeeded in erecting the production facilities within the specified time. The target production rate of 8 rings per day as a first milestone was achieved in May. Another logistic challenge to be mastered will be changing the production process so that each mould is used to produce two segments per day instead of the current one.

T&T



BUILDING SUCCESS

Around the world, VINCI Construction Grands Projets designs and builds large civil engineering structures. Our high level of expertise, strong engineering and management skills, responsive organisational structure and ability to forge well founded local relationships set us apart. VINCI Construction Grands Projets is part of VINCI, the world's leading integrated concession and construction group.

info@vinci-construction.co.uk - www.vinci-construction.com/projets

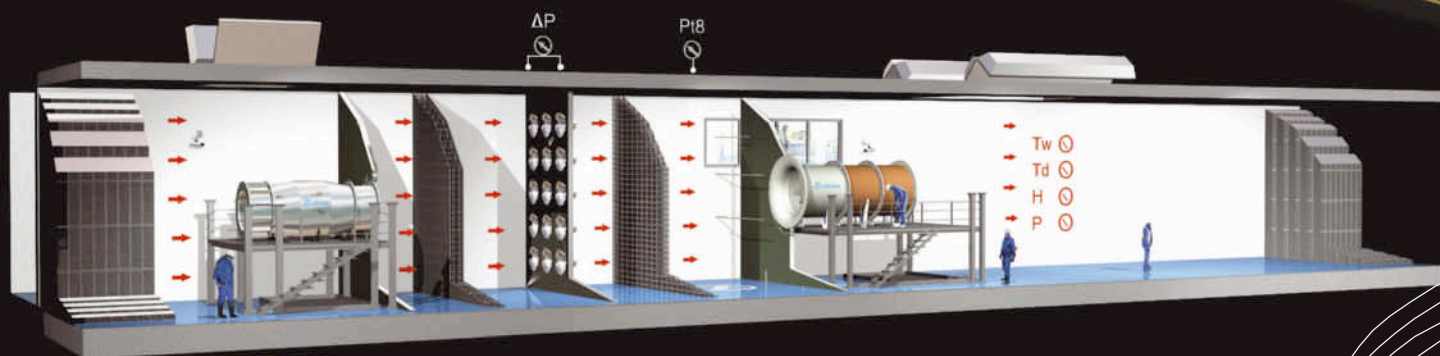
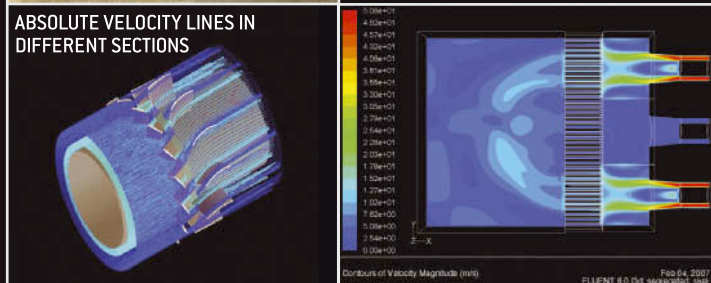
More than ventilation systems

The measure of our experience



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

ABSOLUTE VELOCITY LINES IN DIFFERENT SECTIONS



ZITRÓN, S.A.
Head Office: Ctra. AS-18 N° 2386
33392 Porceyo. Gijón. Spain
P.O. box: 404 - 33280 - Gijón. Spain
Telephone: +34 98 516 81 32
Fax: +34 98 516 80 47
E-Mail: zitron@zitron.com



Probability and risk management

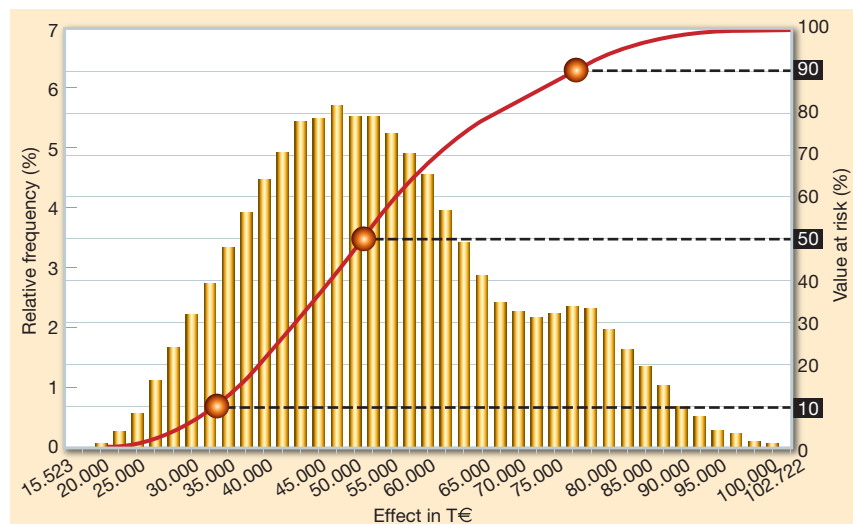
Risk management is the order of the day, especially in large infrastructure projects with a significant share of underground structures, where the risks are generally high. If such a project is performed as a PPP model the demand for an efficient risk management system becomes even more important. For such projects, not only the classic hazards like changed ground conditions and time extensions can cause severe cost overruns but also other factors like lack of funds, increased cost of loans, political uncertainties etc can play their part. A comprehensive risk management system can help to identify the risks and minimize their consequences.

For the owners it is vital to know in advance the final cost as accurately as possible. To achieve this it is common to start with a basic cost estimate and then add a provision for risk - normally a percentage of the basic cost - plus other factors like price escalation etc. This method is only sufficient for simple projects. A single deterministic figure will probably indicate the expected cost, but does not reveal the minimal/maximal cost to be expected, nor does it provide any information on the probability of occurrence.

To cover this the authors propose to quantify risks using probabilistic methods and to consider the uncertainties related to the basic cost estimate by using the same approach. The result is a probabilistic distribution for the basic cost and a probabilistic distribution for the cost of risks. To support this process through all stages of a project the authors developed software called RIAAT Risk Administration and Analysis Tool. It supports the risk management process from identification and assessment of risks through modelling of distribution density to aggregation.

The basis for an application of the tool is the same as for any other method of risk management namely a comprehensive identification and assessment of all risks related to a project. This basic work and the process of updating the risk assessment and the process of risk mitigation and control - often summarized under the term risk management - are supported and

Philip Sander and Markus Spiegl of SSP Bau-Consult GmbH, and Eckart Schneider from University of Innsbruck describe a computational method using probability for managing risk



Above: Fig 1 – Sample of an aggregated risk potential

organized by the tool. The use of probabilistic methods not only for the risk analysis but also for the basic cost estimate is maintained throughout the whole process. The advantage of a probabilistic approach lies in the fact that by using values lying within a bandwidth and modelled by a defined distribution density the reality can be modelled better than by using deterministic figures.

Cost estimate and risk assessment

Cost estimates are always afflicted with significant uncertainties because in the early project stages neither quantities nor prices are exactly known. Furthermore the bill of quantities normally contains only major items; most of the smaller items are missing respectively and are not considered at this stage.

Generally data is derived from completed projects to estimate the cost of a new project, and normally show a considerable spread. Interpreted properly this contains a

lot of information like min/max cost of items and the value most likely to be expected. If, as it is often done, only the mean value or the median is used for the cost estimate, the information on other values, which are less likely to occur, is lost.

The way to transfer this information into the next steps and preserve it throughout the whole process of risk management is by modelling it through a function defining a distribution density and use probabilistic methods throughout all stages of the risk management.

The same applies for risk assessments. If risks are evaluated using deterministic figures instead of considering the bandwidth and distribution density of the probability of occurrence and the financial consequences, the information which is in these figures, is neglected. By incorporating bandwidth respectively distribution density more specific results will be achieved. Figures for a Value at Risk (percentage of the risk-potential), the minimum and maximum costs will become available. Figure 1

Modelling uncertainty

Commercial software for risk analysis provides a number of density distribution functions for modelling uncertainty. A number of them are even incorporated in MS-EXCEL. Commercial risk management software like @risk, Crystal Ball^[1] and others are offering additional features like, risk classifications, risk correlations and aggregation by various methods (e.g. Monte Carlo, Latin Hypercube) besides providing a wide choice of functions. The problem with most of them is that they are too sophisticated for the purpose of cost estimation and risk assessment in civil engineering and require input data and parameters, which are not available for the sort of projects we are looking at. What is missing in all of them are features for the administration and traceable documentation of risks over the various project phases.

Based on earlier works^[2, 3] and experience from research^[4] and encouraged by the positive feedback from pilot projects the authors choose an approach that is more appropriate to the engineering mind; using mainly rectangle and triangle distributions. The first one is utilised to model uniform distributions, the second one for modelling most other distributions. One of the advantages of the triangular function is that it requires only three input data: Expected (most likely) value, minimal and maximal value.

Taking into account that the probability of occurrence for a typical tunnelling risk like a cave-in cannot be deducted from statistics, asking for an expert opinion is often the only way to assess the risk probability of occurrence and consequence. Most experts will be able to indicate the probability of occurrence within a bandwidth – e.g. between 10 and 40% with a value most

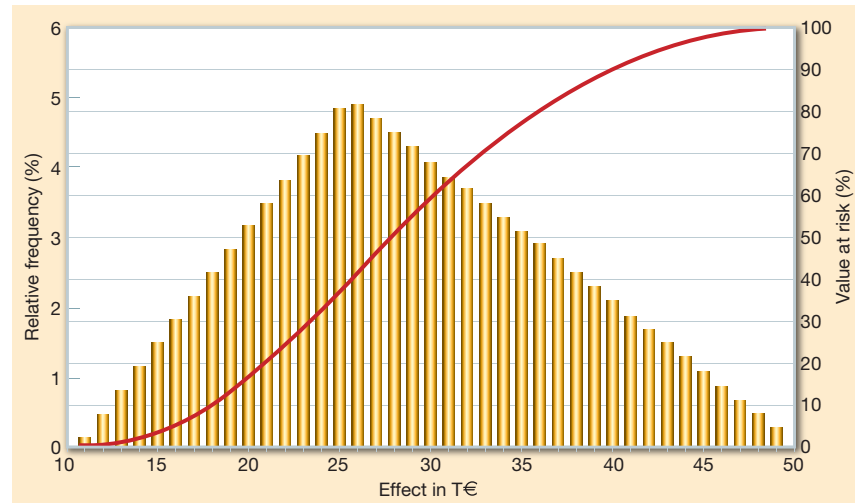
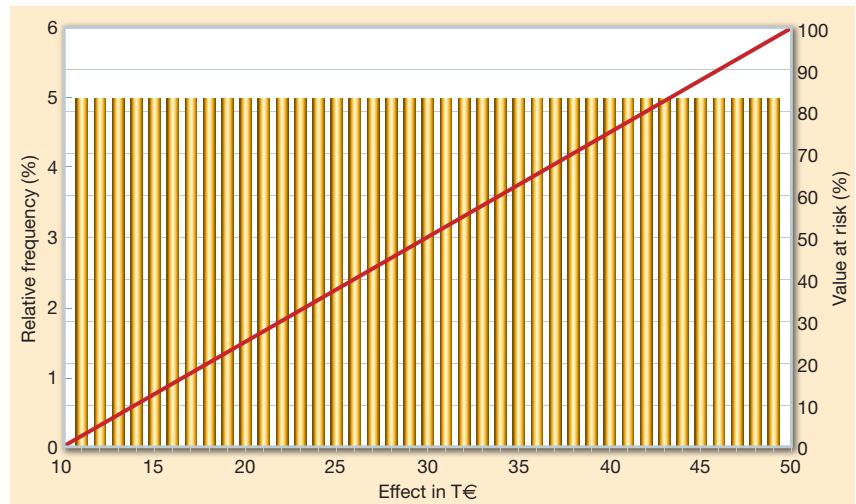


Fig 2a (above) & 2b (below) – Triangle and Rectangle (Uniform) Distribution

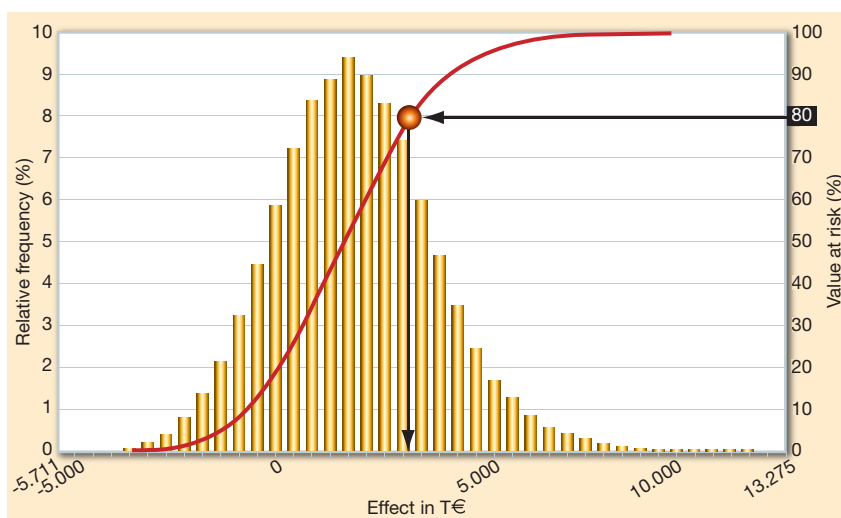


likely to be expected at 20% - as well as the consequences in time and cost within certain limits, this time with a minimal and maximal value plus an estimate for the value most likely to be expected. In this case, as in other cases, where subjective probabilities have to be modelled the use of a triangle distribution will be the best solution (figure 2).

The triangle function is easy to determine and offers considerable flexibility in shape.

The self explaining nature of its defining parameters and speed of use offers a perfect solution for many modelling tasks. An alternative way to keep it simple would be the use of PERT. This is a simplified version of the beta distribution, which does not require more input parameters than the triangle distribution. If putting more probability around the most likely value is advisable it is a good alternative to the triangle distribution^[5, 6]. RIAAT was designed to allow the application of PERT as an alternative.

Another consideration in favour of the triangle function is the aspect that simple basics are essential if quantitative risk analysis using probabilistic methods shall find wider acceptance. It should also be kept in mind that in dealing with uncertainty, increasing accuracy of values does not necessarily lead to higher certainty. In the authors' opinion it is more advisable to determine the accuracy of each value individually by setting the spread and weighting by a "simple" function for distribution densities than using sophisticated functions. Those would be



Left: Fig 3a – Probability Distribution for aggregated risks displaying the same result

June 14-17, 2009 • Caesars Palace • Las Vegas, Nevada



RETC

**RAPID EXCAVATION AND
TUNNELING CONFERENCE**

TAKE A CHANCE

PROGRAM

Conventional/Rock Tunneling	International	New York City
Design/Planning	Las Vegas	Risk Management
Difficult Ground	Lining	SEM
Geotechnical	Microtunnel	Shaft
Ground Modification	Mining	Slurry/EPB
Innovation	New Projects	TBM Case Histories

EXHIBIT

It only happens every two years. Don't miss the industry's premiere showcase for products and services. Of the 150 booth spaces available, 118 are already reserved! Call now and reserve your booth space while they last. For information contact www.retc.org, Dianna Gury, gury@smenet.org, 303-948-4213.

SPONSORSHIPS

An impressive array of sponsorships are available for companies looking to increase their exposure to the global industry. For options see www.retc.org or contact: Heather Bonic, bonic@smenet.org, 303-948-4216.

ADDITIONAL FEATURES

FIELD TRIP

SHORT COURSES

SPECIALTY SPEAKERS

For more information contact: SME, www.smenet.org, www.retc.org, meetings@smenet.org,
303-973-9550, 8307 Shaffer Pkwy, Littleton, CO 80127



only appropriate for risks which can be covered by classical insurance, where statistical methods prevail.

Aggregation of risks

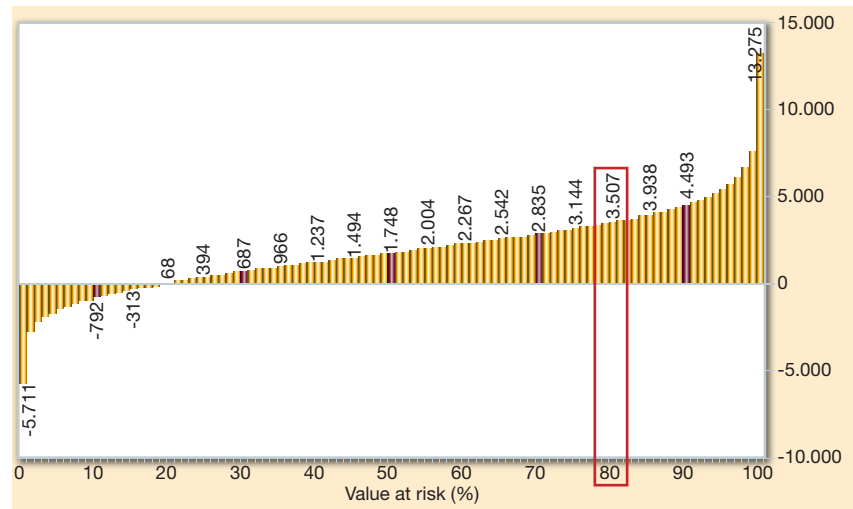
As soon as the distribution densities for the identified risks are determined they can be aggregated using Monte-Carlo-Simulation or Latin Hypercube-Sampling. The result will be again a probability distribution, which displays the overall risk potential. With the figures and distribution curve available the owner can decide, which potential of the risk shall be included in the budget. If the aim is to cover 80% of the risk potential, a figure for Value at Risk 80 has to be determined. Figure 3 shows the determination of Value at Risk 80 using the probability function and the Lorenz curve. Both diagrams are showing the same results in a different exposition. In our example it will be necessary to reserve 3.507 Million Euro to cover 80% of the identified risk potential (figure 3).

Software support

In the preceding text three tasks risk management software should support were identified:

- Modelling of uncertainties in basic cost estimate
- Modelling of density distribution for individual risks
- Methods for aggregating cost items and cost of risks

In addition to these basic tasks good risk management software should provide methods and tools for the administration of the risks over all phases of the project. A number of guidelines and standards giving advice on how to implement an effective



Above: Fig 3b - Lorenz Curve for aggregated risks displaying the same result

risk management and how to structure the risk management process exist. Some^[7, 8] are of scientific and more theoretical nature, some more practice oriented^[9, 10].

Following the general rules of the Austrian guideline and in close cooperation with the project organisation of ÖBB (Austrian Federal Railways) for the Koralm Tunnel the authors have developed their Risk Administration and Analysis Tool RIAAT. It was designed with the purpose of giving computerised support for the whole risk management process and was applied with great success for the risk analysis in the pre-tendering phase of this 38km long railway tunnel in south Austria.

Development and execution of any project is performed in steps or stages. According to^[5, 6] cost estimates and risk analysis should be performed for each of the following phases: Conceptual design; preliminary design; tender design; final design; and project execution.

For each stage a new cycle of risk analysis will be performed. Except from the initial step, where risk catalogues and other basics have to be determined and the risk catalogue has to be set up and risks

identified for the first time, the following cycles are mainly performed by updating. Only between the tender design/final design and project execution stage substantial modifications are required. The reason is that a number of risks, which were originally contained in the portfolio, are reduced or avoided by measures provided in the final design. Others are considered in the contract and thus transferred partly to the contractor (figure 4).

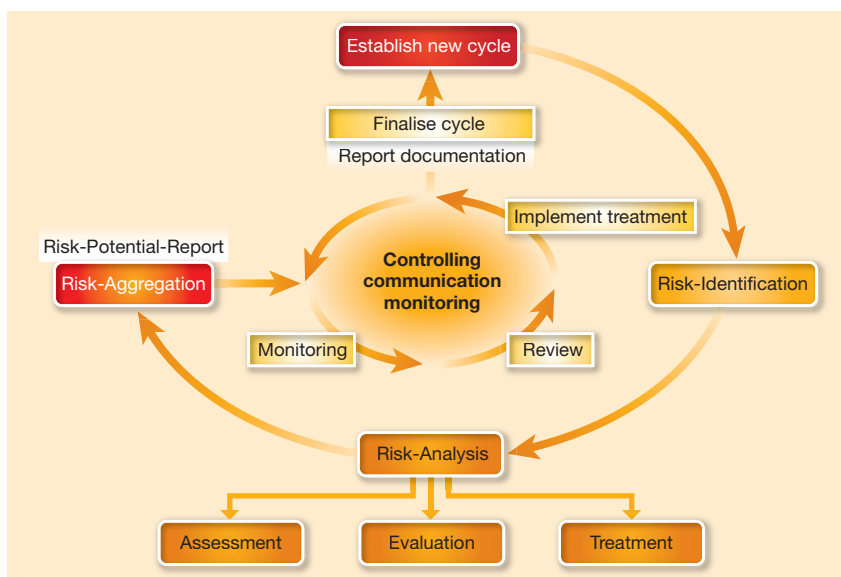
Setting-up the risk management process

In using RIAAT the risk management process starts with determining the basic parameters and structuring the project. Nominating members of the client organisation, design engineers, geologists etc, who shall contribute to the risk analysis and participate in the risk management process and determining the number of cycles and details of the reports, are the main tasks at this stage.

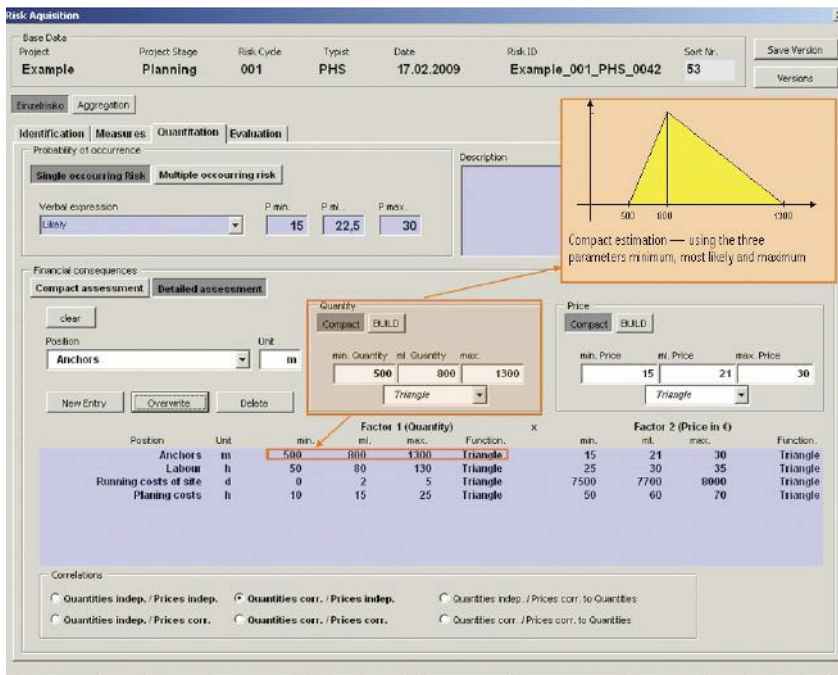
Risk identification - is the first step of the actual risk management process. For this purpose brain storming and check lists etc, can be used. RIAAT provides catalogues for this purpose, which is structured in three or more levels depending on the complexity of the project. This approach allows for assessing and aggregating the risks from bottom up. It further allows determining groups of risk of a similar nature - e.g. unforeseen ground conditions, environmental and political problems etc. - which shall be separately analysed and aggregated. At the same time the tree-structure makes it possible to track each risk back to its origin. A clear structure like the tree structure is also helpful in avoiding redundancies while defining the risks.

Risk analysis

The screen shot in figure 5 shows the input mask for the quantitative risk assessment in RIAAT. The example deals with



Left: Fig 4 – Steps of the risk management process supported by RIAAT



Above: Fig 5 – Quantitative risk assessment with RIAAT

deformations of drilled piles. The risk is characterised through the probability of occurrence and the financial consequences.

In defining the probability of occurrence the user has the choice between a button for risks occurring only once (single occurring risks) and a button for risks occurring several times in one section (multiple occurring risks). It is advisable to describe risks occurring only once by using a deterministic figure indicating the percentage of probability. Multiple occurring risks are characteristic for infrastructure projects like highways, railway lines and tunnel. In these types of projects risks of a similar nature in one section can occur several times at different locations. Examples for tunnelling are falling-ins or the replacement of defective segments of the lining or the correction of surface imperfections in road construction. Such incidents are best described through a figure for the average occurrence. In this case the financial consequences are calculated for each event and summed up to determine the overall risk potential.

The financial consequences for the risk shown in Figure 5 are detailed in four elements: material (anchors), labour cost, running costs of site and planning costs. Each element consists of two factors - quantity and price/cost - each of them can be modelled individually through a distribution density.

In RIAAT modelling the distribution densities of factors is normally done by triangle functions or in case of uniform distribution by rectangle functions. As mentioned before PERT is available as an alternative. Additional flexibility in modelling distribution densities is provided by a module called BUILD. This module allows modelling distribution densities for special cases.

If incidents with a statistical probability like floods or traffic accidents shall be considered, standard functions used in statistics like Normal, Beta, Lognormal could be added to the inventory. The software also foresees the possibility to determine a correlation factor between items/elements and factors. It is also possible to indicate measures to avoid or minimise risks and aggregate these figures together with the cost of risks.

If RIAAT is used for cost finding most procedures are very similar to those described above. There is only one big difference: the probability in cost estimates will always be 100%. The reason is very simple: costs always occur.

Risk aggregation and administration

After having analysed and evaluated all identified risks the aggregation will be the final step of each cycle. The result will be a

probability distribution and Lorenz-curve as shown in figure 1 and figure 3 respectively.

RIAAT provides the means for a comprehensive documentation, which allows for tracking individual risks and the total risk potential over all phases of the project execution. The standard report contains elements like the risk catalogue, diagrams visualising and comparing individual risks by using popular analysing methods and the final aggregation. It includes the costs of risk avoidance or mitigation and a detailed description of the financial consequences. If required a statistical overview of the change in risk potential over the project phases is also available.

Conclusion

Risk analysis and risk management for large infrastructure projects using probabilistic methods offer great advantages for clients and owners. The software developed by the authors, combines tools for risk analysis with methods for comprehensive administration and documentation of changes and updates of risks over the various stages from project development to project execution. The most valuable information it provides is the value at risk at any level and stage. Combined with a cost estimate considering uncertainties related to quantities and costs, it provides the owner with a solid basis for budgeting, risk management and cost control.

The actual version of RIAAT (Risk Administration and Analysis Tool) contains basic elements to assess the time extension related with risks. Efforts will be made to develop this into an additional module/plug-in linked with RIAAT.

T&T

REFERENCES

1. @Risk (Palisade Corporation), Crystal Ball (Oracle), etc.
2. W Fellin, H Lessmann, M Oberguggenberger, R Vieider 2005. Analysing Uncertainties in Civil Engineering, SPRINGER, Berlin
3. P Sander, 2004. Entwicklung einer Methodik zur Identifikation und Verdichtung von Risiken, Master thesis, TU Dresden
4. E Schneider et al. 2006. EDV unterstütztes Risikomanagement und Informationssystem, FFG (Austria) Project No. 808079, Final Report, University Innsbruck
5. D Vose 2008. Risk Analysis – A quantitative Guide, John Wiley & Sons, Chichester
6. M G Morgan, M Henrion, M Small 1992. Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis, Cambridge University Press, Cambridge
7. T Busch 2005. Holonistisches und probabilistisches Risikomanagement-Prozessmodell für projektorientierte Unternehmen der Bauwirtschaft, Doctor thesis, ETH Zürich
8. N Da Costa Lewis 2004. Operational Risk with Excel and VBA: Applied Statistical Methods for Risk Management, John Wiley and Sons, Chichester
9. Austrian guideline 2005. Kostenermittlung für Projekte der Verkehrsinfrastruktur, ÖGG – Österreichische Gesellschaft für Geomechanik, Vienna
10. Austrian federal railway – ÖBB 2007. Handbuch zur Kostenermittlung, ÖBB, Vienna

www.tunnelsonline.info

...the ultimate tunnelling resource

The latest news

tunnelsonline media partners



www.herrenknecht.com



www.dywidag-systems.com



www.vmt-gmbh.de



www.helogistik.de



www.ugc.basf.com



Recruitment, Digital
Issue and Archive

What more could you ask for?

a world of information fully
archived and searchable at
the touch of a button





Concrete casting

Above: A typical tunnelling project concrete batching plant [Photo: Jacobs]

Concrete can be supplied to tunnel projects from commercial ready-mix concrete suppliers to specification. Alternatively an on-site or nearby batching plant can be justified by the economics of scale, the remoteness of the site or special mix considerations. CIFA offers a wide range of equipment applicable to concreting in tunnels including formwork, transport products, mobile mixers, pumps and batching plants. Depending on the design, these plants are made to produce output according to changing requirements and improve overall efficiency, especially in supply.

Transport

The main practical choices for getting concrete to its point of use in tunnels are greatly affected by the section of the tunnel and where it is practical to locate the batching plant. Depending on the logistics of the tunnel, drop-chutes, hopper or mixer trucks on rails or tyred vehicles, belt conveyors, and long distance pumping can all play a part.

During construction of the railway extensions to London's Heathrow Airport Terminal 5, concrete pumping specialist Pochin supplied a static pump with 240kW

In the field of cast in-situ lining, recent trends in customer requirements in addition to cost efficiency include better fuel economy, work-ability over longer periods, greater pumping parameters, faster erection and removal of formwork. Maurice Jones reports

diesel drive with site operator and 1800m of pipe to deliver concrete over this distance, claimed to be a record. The US\$367,500 contract surpassed previous record work for Balfour Beatty on Terminal 4.

Pochin's fleet features the Putzmeister PUMI combination truck-mounted concrete pump and mixer. The compact 8-wheel vehicle has a turning circle of 21.5m and carries the TMP 60 CS pump and TMM 21 boom. Output is up to 56m³/h and a maximum delivery pressure of 57bar. The Z-fold boom system carrying a 100mm diameter delivery line has a vertical reach of 20.6m and a net horizontal reach of 14.5m.

Maxon Industries, based in Indiana, originally developed open-top concrete transport dumpers for paving, and then developed Agitor models which prevented the mix for separation over long transport runs. Underground activities began with the 1980s development of the Maxcrete, a low-profile, open-top carrier for mine development featuring a full-sweep paddle design for complete remixing/retempering of

the concrete. These units can be skid-mounted or carried on rail or tyred vehicles. Recent developments include:

- a patented high-dump swing-away chute for Agitors
- a self-powered Mobile Maxcrete specially for tunnelling
- the Maxon Maxslide that can dump to either side and rear of the carrier on a turntable arrangement
- employment of a Maxcrete as a surge hopper for a concrete pump whilst being reloaded by Agitors or rail wagons for rapid concrete placement

The Mobile Maxcrete can travel at 10mph on a bi-directional chassis running on the tunnel invert. Maxon also has a range of concrete handling and placement equipment especially for small-bore tunnelling.

As one of the best known manufacturers of rail-based equipment for tunnelling and mining Mühlhäuser supplies specially designed cars for concrete transportation including remixers, silo cars, and cars for ingredients such as aggregate and cement.

Your centre of excellence
for tunnel lining systems

CERESOLA +tls
TUNNEL LINING SYSTEMS



- tunnel formwork systems
- segment moulds and pre-cast concrete segment production plants
- steel support systems for excavations
- canopy tube systems

Ceresola TLS AG ~ Brüelstrasse 26 ~ CH-4312 Magden
Tel. +41 (0)61 845 93 40 ~ Fax +41 (0)61 845 93 41 ~ info@ceresola.com ~ www.ceresola.com



*"Safe Tunnelling For The City
and For The Environment"*



ITA-AITES WORLD TUNNEL CONGRESS 2009

and the

35th ITA-AITES General Assembly
Budapest, Hungary • May 23–28, 2009



For the list of accepted abstracts,
list of sponsors and exhibitors,
registration details and 3rd bulletin
please visit

www.wtc2009.org



Left: Multiple concrete placement tasks were carried out in the underground Kopps II power station using a Putzmeister stationary boom MX 284 with a 'Z'-fold system and fed alternately by two columns.

Placement

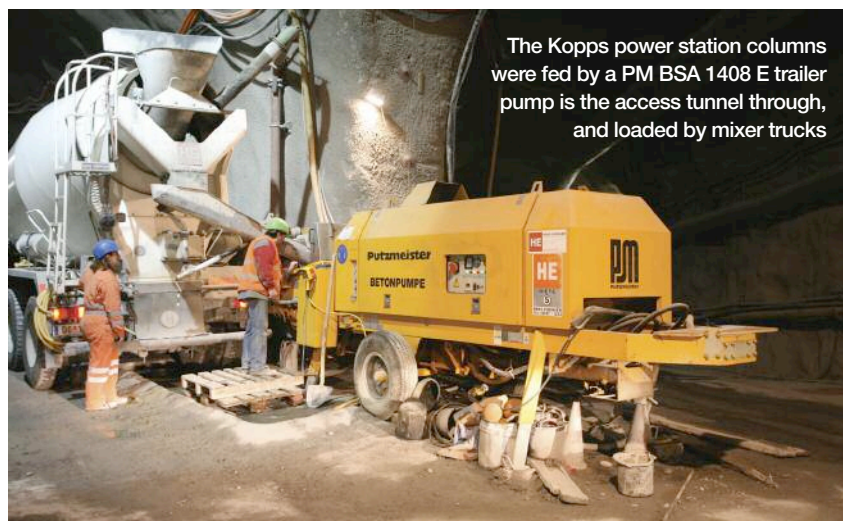
One of the latest applications of Putzmeister concrete pumps and placement equipment is the 12.8km long Lainzer Tunnel for trains through Vienna. Models employed include the BSA 2109HE pump and the models BSA 1408 E and BSA 2104 HP E. The first pumped concrete over 350m at rates of around 40m³/h.

Segment backfilling was another recent project for six Putzmeister KOV DUO 550 PM pumps on Madrid's M30 tunnel project. The pumps are equipped with ball valves to control the pump in feeding two separate delivery lines. Four further KOV 1050 ball valve pumps were used to transport mortar material from silos, with controls integrated with the other six units on the TBM back-up system. The system was used over three shifts, seven days a week. The FCC- Dragados contracting consortium also leased a truck-mounted Putzmeister concrete pump from Ibérica de Bombeos Especiales for various other concreting jobs on site. This included feeding a BSA 2109 stationary pump from the tip of its boom for long-distance pumping. In a relay operation this delivered the concrete up to 600m through a SK pumping line.

Since becoming part of the Putzmeister group in 2007, Allentown (now Allentown Shotcrete Technology Inc.) has been offering the Putzmeister range of BSA trailer concrete pumps and Snorkel distributors. Although mainly for wet process shotcreting, these units are also applicable to concrete placement duties in major projects.

The largest trailer pump in the range is claimed to offer the highest pressures and outputs available today, with a maximum theoretical pressure of 220bar and maximum delivery of 102m³/h on the piston pump from a 470kW Caterpillar diesel drive. The TSV 5-12 Snorkel, as the largest standard distributor unit in mounted with rails together with a extendible pipe scissor system, also on rails, and powered by a 15kW hydraulic power pack. The telescopic 'snorkel' unit can turn through 360 deg. The pipe diameters are 125 or 150mm.

Concrete Pumps of Durban, South Africa, has been supplying the simple and economical air-powered SEM concrete placer pump for forty years. Since the 1980s



The Kopps power station columns were fed by a PM BSA 1408 E trailer pump is the access tunnel through, and loaded by mixer trucks

it has added piston-type concrete pumps including models from the Putzmeister and Thom Katt ranges. The Company also proposes solutions to concrete placing problems and commission the equipment until it is successful.

SEM Concrete Placer Pumps are said to cost only 10-13% of the price of a conventional piston pump, and has no moving parts to maintain or break down. The pumps can operate continuously or in several plug batches, the latter to enable the maximum placement distances and heights to be increased. So far up to 400m horizontally has been achieved. SEM Pumps have been used as trailer-mounted units on the Khimti 1 hydropower project in Nepal, and for a new underground pump station at the Blyvooruitsicht gold mine, South Africa.

The latest model from Tek.Sp.Ed under the Bunker trade name is the versatile B100XP combined mixer, pump and spray system that can handle shotcrete and plastering as well as concrete placement. The diesel hydraulic drive, trailer-mounted unit is designed to mix on-site. The mixer has a 350l capacity, a screw pump, and a loading skip with a digital weighing machine. The pump has a maximum theoretical output of 250l/min with a maximum pressure of 12bar, pumping distances can be up to 60m horizontally and 20m vertically.

With a catalogue of over 20,000 part numbers, Construction Forms (Con Forms)



Above: Ceresola's invert shuttering currently being used in the Zurich Weinberg Tunnel for SBB

of Wisconsin, US, offers a very wide range of piping systems used in concrete mix transport and distribution. This includes a special Tunnel Placer design to meet the requirements of each project. Features include a boom to rotate through 300 deg., jib extensions such as horizontal and vertical scissor systems, and various power options. The Company has a European operating division in the UK and Con-Forms Asia based in Johor Bahru, Malaysia.

Formwork

In order to cast the poured concrete tunnel lining or other construction into the required shapes, thicknesses and perhaps surface finish, some type of formwork will be

necessary. This could be custom designed and made on-site, employ a proprietary modular system of standard components, or use various types of specialised tunnel standard or custom designed formwork. Site fabricated formwork is generally non-viable except for small constructions, by site assembled modular systems are widely used for cut-and-cover tunnels and non-standard sections. Some manufacturers design specially systems for arch shapes.

Specialist tunnel travelling formwork is viable for longer runs of tunnel, and can be easily renovated for use in subsequent projects. The 'travelling' principle of location and erection offers several advantages but principally timesaving. Ceresola Tunnel Linings Systems offers formwork of steel and steel/timber combinations to custom designs or standard sections. Types include formwork for roof vaults, inverts, and full sections, suspended slabs, niches and cross passages, together with similar products for erections concrete reinforcement and exterior forms for 'false' tunnels and avalanche protection. Recent applications include California's longest highway tunnel, the Devil's Slide Tunnel, and the Weinberg Tunnel for the Swiss Federal Railways in Zurich. The Devil's Slide twin-bore tunnel uses two steel forms 10m wide x 8m high and 12m long. The order also included a rebar placing gantry, three concrete curing gantries with controls to prevent microcracking, and special forms for niches and by-pass passages. The Weinburg order included and invert form for the 5km long TBM drive.

Doka's large-area Top 50 formwork, often used in tunnel construction, features made-to-measure designs from a modular system of only three system components including timber beams. The shape, size, anchor pattern and sheeting of the panels adapt to suit any set of requirements. The many recent tunnel references include the



Above: Doka formwork being used on the Steinhaus Tunnel

Lötschberg Tunnel in Switzerland and, in cut-and-cover, the twin-tube motorway Steinhaus Tunnel.

Part of the Lötschberg base-rail tunnel featuring Doka formwork was the Adelaarain Fork where an adaptable travelling formwork unit was used with Top 50 large-area formwork to line the funnel-shape cavern at Frutigen. Within a length of 275m the SATCO joint venture formed a circular section tunnelling from 18.1m to 7.6m wide and 9.95 to 7.95m high. The formwork was folded down hydraulically and re-erected after each pour. For the Steinhaus Tunnel Top 50 was used in more conventional rectangular sections over 2400m but to form the concrete in a single pour as a 'White Tank' impermeable mass with no additional waterproofing skin. All formwork movements were controlled by a single steering unit to move to the next pouring step.

A trend to 'fair-face' concrete for architectural aesthetic properties using only the right concrete as a material can also be involved in tunnel construction in, for example, metro stations for public access, improve lighting or a better surface for decoration. Both Doka and Peri are among those meeting this need. As part of the B17 ring road around Augsburg, Germany, Züblin used formwork based on Peri's GT24 girder system with a hydraulic formwork machine to carry out weekly pours. The cut-and-cover construction was set in an excavation supported by overlapping bored piles and sheet piling. To ensure water impermeability the closed-frame construction used waterproof, reinforced concrete, with monolithic pours of the base and walls avoiding construction joints.

Materials

As for concrete for spraying and pre-cast construction the mixes used for cast in-situ concrete will be designed to meet the peculiar conditions of transport, placement and performance required once cured. In

this context retarders and plasticisers to promote and extend work-ability and pumpability are likely to be of importance.

Whilst the inclusion of fibres is often associated with sprayed concrete, the products of Bekaert and IFT Fasertechnik have been used for cast in-situ linings. Steel fibres have been used to improve the toughness of concrete, especially near the surfaces, and sometimes supplement or replace conventional reinforcement. Polymer fibres have also been used for structural and fire alleviation purposes.

IFT's Duoloc steel fibres provide 'double locking' in the mix by hooks at both ends of the fibre and corrugations along its length. Unoloc is a version only with end hooks. Duoloc is also available in Trioloc mixes in combination with Polyloc polypropylene fibres. Microloc ultrafine polymer fibres are also available for the alleviation of possible fire damage.

The frequently tricky problem of TBM entry and exit points in shafts has been tackled by the development of 'soft eye' structures for easier, sealed passage of the TBM cutterhead. The thick-walled weaker concrete approach of early developments has an alternative with the production of glassfibre-reinforced plastic (grp) reinforcement panels as produced by Fortius of Belgium and Sireg of Italy. Such panels made from Fortius Aslan 100 GRP rebar were used for four station passages in slurry wall construction on the first phase of the Dubai Rapid Link (DURL) metro. These required nine 'soft eye' structures in all. The rebars are easily cut by the TBM.

With concerns about the sustainability and environmental effects of concrete construction, especially carbon dioxide emissions, there has been greater interest in special blended concrete mixes. The use of pozalans, as specially manufactured, natural or by-products from other processes, can reduce carbon dioxide emissions, improve performances and lower cost. These advantages may have to be balanced against concerns about fresh concrete behaviour, rate of gain in properties such as strength and durability in extremes of weather. As a manufactured material and a by-product from silicon and ferrosilicon processes Elkem Microsilica from Elkem Materials can be used to increase strength and impermeability of concrete. Many ternary blends employ Microsilica together with fly ash and ground granulated blast-furnace slag (GGBS) in the blended mix, to combine the high performance of Microsilica with cheaper, more available supplementary cementing materials with drawbacks such as slower performance rate increases. T&T



Above: The Doka formwork used for the Adelrain Fork section of the Lötschberg Tunnel at Frutigen by SATCO

Classified

Contact Frank Bloomfield T: +44 (0)20 7336 5283 E: fbloomfield@progressivemediagroup.com F: +44 (0)20 7336 5201

RECRUITMENT



A unique opportunity exists to register with **Tunnel Force** and join tunnelling projects located in Australia and Asia.

We are currently seeking expressions of interest from qualified and/or experienced:

- Project Managers • Design Engineers • Shift Engineers
- Superintendent - General, Tunnel, Mechanical and Electrical
- Tradespeople - Fitters, Electricians and Boilermakers
- Technicians - Hydraulic and PLC
- Operators - TBM (Hard Rock, EPB), Pipe-jacking and Road Headers
- General Shift Supervisors & Tunnel Builders

Register your interest by emailing your CV to contact@tunnelforce.com.au



Tunnel Design Manager - London - £65K + Benefits

Leading a multi-disciplinary design team on a major infrastructure project involving tunnels and underground stations. Seeking CEng with management experience.

Geotechnical Engineer - Surrey, UK - to £45K

Design of deep foundations, retaining walls and cut-and-cover tunnels.

Tunnel Engineers - UK - to £40K + Car & Benefits

Experience of TBM projects, supervising site works on major tunnel project.

Tunnel QS - London - to £47K + Car & Benefits

Experienced QS required with knowledge of tunnelling.

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



www.coyles.co.uk/tunnelling

Hunter Personnel

Specialists in Tunnelling, Civils and Construction Recruitment.

- Ref: PN3861 Tunnel M&E Design Engineer, Surrey, UK
- Ref: PN3871 Tunnel Design Engineer, Greater London, UK
- Ref: PN3864 Engineering Geologist, Australia
- Ref: PN3862 Principal Tunnel Engineer, Surrey, UK
- Ref: PN3863 Tunnel Design Engineer, Hong Kong

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

www.hunterpersonnel.com



International Tunnelling Services
Professionals in tunnelling

With teamwork to the breakthrough.

Are you looking for experienced personnel to work on your tunnelling projects?

We are specialised in tunnelling recruitment solutions. We are able to supply qualified personnel of all levels, from back-up labour to project manager.

Experienced personnel of different nationalities.

Do you require an efficient, prompt and accurate solution to your recruitment need?

Please contact us to discuss your requirements.

E-mail: info@tunnelcrew.nl

www.tunnelcrew.nl

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



Engineering Recruitment UK & OVERSEAS OPPORTUNITIES

- **Tunnel Site Engineers – Vietnam - Attractive salary & Benefits**
The project is Hydropower with shafts & tunnels driven by TBM.
 - **Tunnel Project Manager – Dublin**
This rail project includes twin TBM bored tunnels & excavated underground stations. Similar project experience required.
 - **Senior Tunnel Design Engineers – Hong Kong - Attractive salary & Benefits**
Experience in design and construction of tunnels and corresponding geotechnical works (TBM tunnels, Soft Ground tunnelling, NATM tunnel and Rock Caverns).
 - **Tunnel Design Engineers – UK & Overseas**
Experience of Immersed, TBM, NATM, SCL & Cut & Cover Tunnels.
- For further information on these & other opportunities, please contact Daniel Lee-Billinghurst.
Tel: +44 (0) 207 754 5999 Email: careers@v-engineeringrecruitment.com
Web: www.v-engineeringrecruitment.com

tunnels & tunnelling classified advertising

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

in print **I** and **I** on-line - contact Frank Bloomfield

T: +44 (0)20 7336 5283 E: fbloomfield@progressivemediagroup.com

WEBSITE DIRECTORY



HOLDTRADE (UK) LTD
holdtrade@holdtrade.co.uk
TEL: +44 (0) 208 293 5999
FAX: +44 (0) 208 293 7123

Tunnelling and Mining RAILWAY SUPPLIES

Rails from 7kg/m up to 60kg/m plus full range of accessories including: Fishbolts, Steel Sleepers, Fishplates, Rail Clips.

Locomotives & Rolling stock
www.holdtrade.co.uk



MINOVA

Minova CarboTech GmbH

Waterproofing - Consolidation - Bolting

Phone: +49 201 172 1038
Fax: +49 201 172 1317
Email: info@minova-ct.com
www.minova-ct.com
www.minovainternational.com



hoelscher dewatering

- dewatering
- groundwater control
- water treatment

www.hw-dewatering.com



• Leak Sealing • Soil Stabilisation
• Structural Reinforcing • Ground Water Control • Disaster Recovery

OXFORD HYDROTECHNICS
Tel: +44(0) 1869 346 001
info@h2ox.net
WWW.H2OX.NET

A.S.T. Bochum
Armaturen- Schlauch- und Tunneltechnik

Special fittings, hoses and tunneling equipment for:

- Erection plant
- Machine requirements
- Microtunneling
- Drill & Blast tunneling
- Air pressure supply
- Concrete formwork engineering
- Special civil engineering
- Shot concrete engineering
- TBM tunneling
- Freezing engineering
- Wearing protection
- Draining

Tel: +49 (0)234 / 599 63 10 - Fax: +49 (0)234 / 599 63 20
www.astbochum.de

Tunnel, Caisson & Cavern

BABENDERER ENGINEERS

Worldwide engineering service with experience in all types of geology and construction techniques

- ◆ Design Assistance
- ◆ Consulting
- ◆ Construction Management
- ◆ Technical Assistance

Germany, USA, Brazil
www.babeng.com



PALMIERI ROCK TOOLS

LEADERS IN ROLLER CUTTERS AND TOOLS MANUFACTURE FOR ALL TYPES OF TUNNEL BORING MACHINES, MICROTUNNELLING UNITS AND VERTICAL DRILLING EQUIPMENT OF ALL MAKES, EITHER STANDARD OR CUSTOM DESIGNS

PH. +39 0534 32511
FAX + 39 0534 32501
sales@palmierirocktools.com
www.palmierigroup.com



SCHAUENBURG TUNNEL-VENTILATION GMBH

Flexible Ventilation Ducting

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

Sp SPECIALIST PLANT

TUNNELLING EQUIPMENT HIRE & SUPPLY

Specialist Plant Associates Ltd

Agents for **CIFA**

Tel: +44(0) 1234 781 882
Email: info@specialistplant.co.uk
www.specialistplant.co.uk

ALAN AULD ASSOCIATES

TUNNEL AND SHAFT SPECIALISTS

Telephone +44(0) 1302 329911
Fax +44(0) 1302 329922
Email mail@alanauld.co.uk
Website www.alanauld.co.uk

The **one-stop** source for the **tunnelling industry**.

It's only a **mouse click** from here!

tunneltrade.com
your tunnel internet portal



CAVIDRAIN

Groundwater Drainage for Tunnel Walls & Invert

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

MASCHINEN - UND STAHLBAU DRESDEN

NIEDERLASSUNG DER HERRENKNECHT AKTIENGESellschaft

Your partner for special solutions in the tunnelling sector.

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



QA PHOTOS

'Experience in depth'

Tel: +44 (0)1303 894141
Email: pix@qaphotos.com
www.qaphotos.co.uk

HERRENKNECHT

Tunnelling Systems

www.herrenknecht.com

E.P.B. Foam Specialist

E.P.B. foams & Additives

Your partner in TBM tunnelling

MATOMA BV

Tel: 0031-43-3653130
Matoma@planet.nl



MERGOR
UNDERWATER CONSTRUCTION

www.mergor.com



H+E LOGISTIK GMBH

www.helogistik.de



VMT

www.vmt-gmbh.de



CONTINENTAL
CRUSHING & CONVEYING



vidaLaser

Custom design and manufacture of tunnel laser

Visit our website for datasheets and application notes
www.vidalaser.com

You could advertise on this page

and target 14,000+ tunnelling professionals every single month - including the 900+ BTS members

No other tunnelling magazine delivers a readership of this quality

Tunnels & Tunnelling International - the only dedicated monthly international tunnelling magazine

Contact Frank on Tel: +44 (0)20 7336 5283
Email: fbloomfield@progressivemediagroup.com

Dates & Events

4 MAY

Seattle Regional Tunnelling Conference, Seattle, USA

Organised by the Underground Construction Association of the Society for Mining, Metallurgy and Exploration, and held at the Seattle Sheraton, this one day conference will talk about the past, present and future of Seattle's tunnels, and also several international projects. Contact: UCA of SME; Fax +1 303 979 3461; web: <http://www.smenet.org>

6-7 MAY

1st International seminar on Safe and Rapid Development Mining, Perth, Australia

Organised by the Australian Centre for Geomechanics, themes will include: Risk and safety; Ground support and rehabilitation; Development blasting; Equipment and automation; Vertical development: shafts and rises. Contact: Australian Centre for Geomechanics; email: acginfo@acg.uwa.edu.au; Tel: +61 8 6488 3300; web: <http://www.acg.uwa.edu.au>

18-20 MAY

8th Iranian Conference on Tunneling and Underground Spaces Tehran, Iran

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

23-28 MAY

2009 ITA World Tunnel Congress Budapest, Hungary

The 35th ITA General Assembly and Congress will be held in Budapest. With a large amount of tunnelling underway and in planning, the organisers are confident it will be a successful event. Contact: Diamond Congress; email: secretariat@wtc2009.org; web: <http://www.wtc2009.org>

07-10 JUNE

Shotcrete for underground support XI Davos, Switzerland

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

14-17 JUNE

RETc 2009 Las Vegas, Nevada, USA

RETc is recognised as one of the world's leading international tunnelling event for contractors and engineers. Last year, conference attendance exceeded 1500 professionals from more than 30 countries and the exhibition sold out in record time. With a venue of Las Vegas, 2009 is sure to be even more of a success. Contact: SME; web: <http://www.retc.org>

17-19 JUNE

Swiss Tunnel Congress '09 Lucern, Switzerland

Held in Lucern, the event spans two days at the city's Culture and Congress Centre and a final day of field excursions. Day 1 features a training conference with TBM tunnelling in soft ground as the topic. Day 2 sees presentations given from local and international tunnelling projects. Contact: Thomi Btäm; email: fgu@thomibraem.ch; web: <http://www.swisstunnel.ch>

22-25 JUNE

5th Symposium of Strait Crossings Trondheim, Norway

Organised by SINTEF and the Norwegian University of Science and Technology, this major symposium aims to act as a forum for the exchange of information, research, new technology and recent experience. The event will also include an exhibition. Contact: NTNU; email: sc09@adm.ntnu.no; web: <http://www.straitcrossings.com>

09-11 SEPTEMBER

IBTTA 77th Annual Meeting Chicago, USA

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

13-16 SEPTEMBER

EURO:TUN 2009 Bochum, Germany

The 2nd International Conference on Computational Methods in Tunnelling is organised by the Institute for Structural Mechanics. Contact: Conference Secretariat; Tel: +49 234 32 29051; web: <http://www.eurotun.rub.de>

16-18 SEPTEMBER

Tunnel Construction and Underground Structures, Ljubljana, Slovenia

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

08-09 OCTOBER

58th Geomechanics Colloquy 2009 Salzburg, Austria

The popular annual two day event will be held in the Salzburg Congress Centre with session topics including Projects in Austria, Grouting in Rock, Deep Tunnels, and Reuse of tunnel excavated material. Contact: OeGG; email: salzburg@oegg.at; Web: <http://www.oegg.at/events/geomechanics-colloquy>

01-03 DECEMBER

STUVA TAGUNG'09 Hamburg, Germany

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

BRITISH TUNNELLING SOCIETY

21 MAY: AGM and A3 Hindhead Tunnel

Following the Annual General Meeting of the BTS, a presentation will be given by contractor Balfour Beatty on the construction of the UK's longest road tunnel. 6pm start at the ICE

18 JUNE: The Pinheiros Station collapse

Lessons learned from the station collapse in Sao Paulo will be explained by Prof A Assis, and Dr J Barros from the Sao Paulo Institute for Technical Research. 6pm start at the ICE

17-19 MARCH 2010

ISTSS 2010 Frankfurt, Germany

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

14-20 MAY

2010 ITA World Tunnel Congress, Vancouver, Canada

Prior to the 2010 Winter Olympics, the International Tunnelling Association (ITA) visits the spectacular city of Vancouver, British Columbia, for its yearly conference and exhibition. Contact: web: <http://www.wtc2010.org>

8-10 JUNE

InterTunnel 2010 Turin, Italy

Tunnelling exhibition aimed at those involved in building and equipping tunnels. Contact: Mack Brooks Exhibitions; web: <http://www.intertunnel.com>

A DATE TO REMEMBER...

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

Contacts

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

WEB
www.tunnelsonline.info

TEL
+44 20 8269 7789

FAX
+44 20 8269 7840

HOW TO CONTACT US

EDITORIAL

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

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

CONTRIBUTING EDITOR
Patrick Reynolds MEng
Tel: +44 20 8269 7748 Fax: +44 20 8269 7840
Email: patrickjreynolds@hotmail.com

DESIGN
Natalie Kyne

TECHNICAL ILLUSTRATOR
Nick Stenning

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

ADVERTISING

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

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

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

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

PUBLISHING

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

HOW TO SUBSCRIBE

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

Subscription price (12 months) mailed anywhere in the world: US\$239 / £147 / 220 (UK only £99.00). Claims for missing subscribed copies can only be entertained within three months of publication.

HOW TO GET BACK ISSUES

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

HOW TO GET REPRINTS

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

REPRO/PRINT

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



All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage or retrieval system, without the express prior written consent of the publisher.

The contents of Tunnels & Tunnelling International are subject to reproduction in information storage and retrieval systems. Contact: University of Microfilms International, 300 N. Zeeb Road, Ann Arbor, Michigan 48106, US.

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

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

Tunnels & Tunnelling International and its Editorial Board accept no responsibility for the accuracy of statements or opinion given within the Magazine that is not the expressly designated opinion of the Magazine or its Editorial Board. Those opinions expressed in areas other than editorial comment may not be taken as being the opinion of the Magazine or its staff, and the aforementioned accept no responsibility or liability for actions that arise therefrom.

BTS - EDITORIAL ADVISORY BOARD

Editorial Advisory Board Chairman:

Myles O'Reilly ME, PhD, CEng, FICE
Committee: Keith Bowers MSc, PhD, CEng, FICE, MIMMM, FGS; David Court CEng, FICE; Robert Ibell BSc(Eng), CEng, MICE; Tom King CEng, FIMMM; Roger Margerison BSc, CGeol, FGS; Barry M New MSc, PhD, CEng, MICE; Andrew Smith CEng, MICE; Ken Spiby, BEng; Ivor Thomas CEng, MICE; Nathan Wilmot MEng, ACGI, CEng, MICE, MHKIE



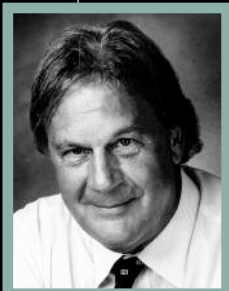
Tris Thomas



Amanda Foley



Gary Tween



David Wildman

EVERY STEP OF THE WAY.

Robbins has more than just expertise, experience and industry-changing TBMs. From geological reports through to project execution, Robbins is by your side, assisting you with your most important project: the one in front of you.

Collaboration personified.

therobbinscompany.com
sales@robbinstbm.com



In-depth expertise.

More than 1000 km of tunnels for transportation infrastructure and more than 1000 km of shafts and water tunnels - our experts apply state-of-the-art techniques in the development of integrated and cost-effective solutions for tunnelling projects.

Pöyry's knowledge extends across hydropower, oil & gas, power & heat, renewable energy, pulp & paper industry, chemical process industry, transportation, water & environment, and construction services. We employ 8000 experts in 49 countries.

PÖYRY

Consulting the life-cycle of underground structures
helps to avoid future problems:
tunnelling.transportation@poyry.com



Competence. Service. Solutions.

www.poyry.com