

MAY 2008

tunnels & tunnelling

INTERNATIONAL

ROBBINS ON AMR

The first of two 10m diameter Robbins double shield TBMs was launched recently to begin excavation of a 43.5km water tunnel for the Alimineti Madhava Reddy scheme in India



One breakthrough after another.

Innovation.



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

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

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

Visit us at www.robbinstbm.com.



MAY 2008

tunnels & tunnelling INTERNATIONAL



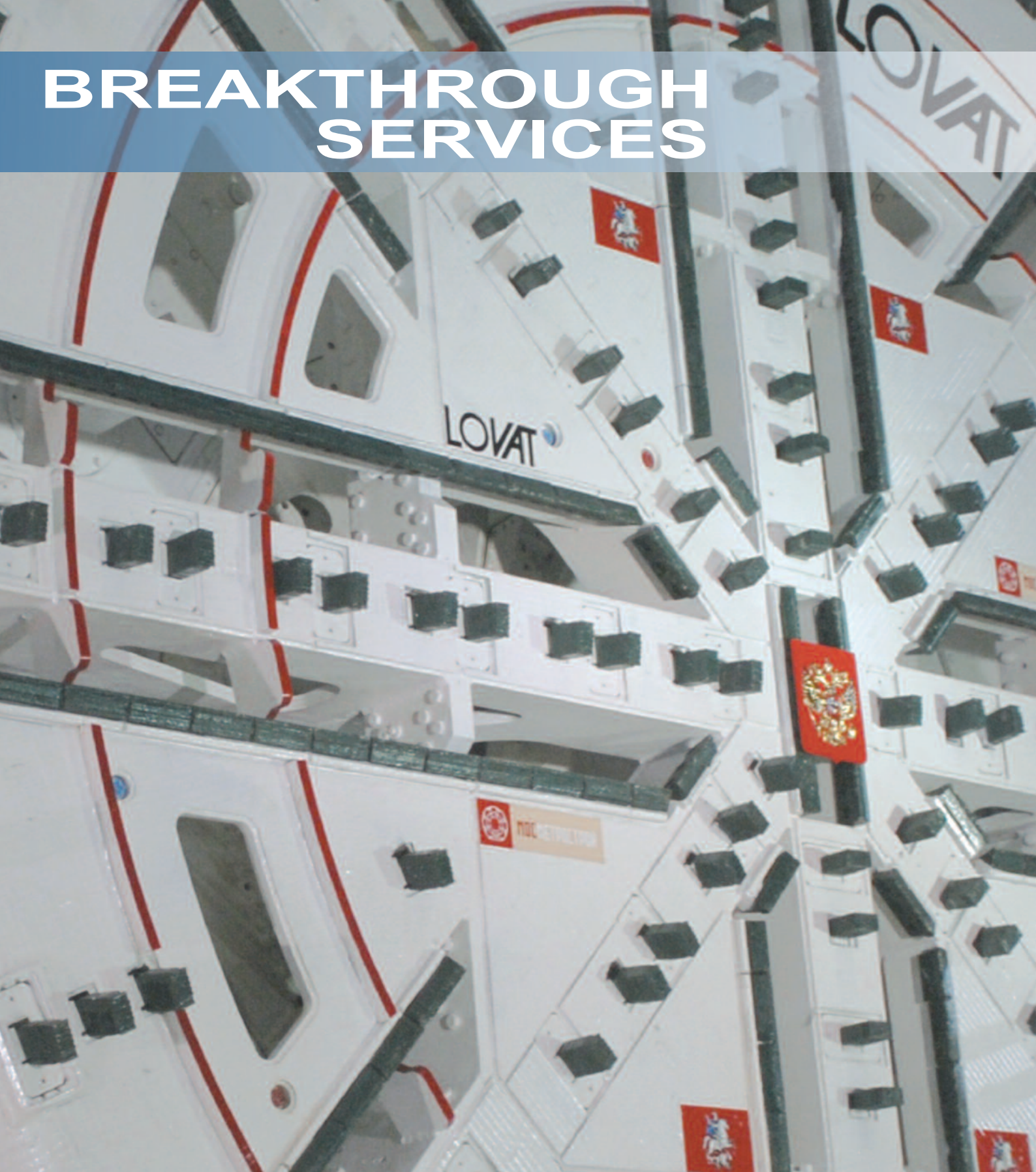
FOCUS ON THE MEDITERRANEAN

The Lyon-Turin Base Tunnel and the Bosphorus Crossing are discussed

WATERPROOFING

T&TI takes a look at the latest in waterproofing technology

BREAKTHROUGH SERVICES



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



PROJECT MANAGEMENT
OPERATOR TRAINING
TUNNELLING TECHNICAL SERVICES
SITE MANAGEMENT SERVICES

LOVAT

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

Contents

FRONT COVER:
A crushed excavator, with 'molded' debris caught in its folded limbs, is uncovered during the collapse recovery at São Paulo Metro, in Brazil (p27)

WEB ADDRESS
www.tunnelsonline.info

CONVERSIONS
US\$1.00
€0.64
£0.51

5 COMMENT

6 WORLD NEWS

12 BUSINESS & FINANCE

MEDITERRANEAN FOCUS

15 LYON-TURIN BASE TUNNEL

Saint Martin Squeeze

Research into overcoming squeezing ground during early works for the Lyon-Turin Base Tunnel is discussed

21 THE ISTANBUL CONNECTION

Across the Bosphorus and beyond

A review of the ambitious rail link between Asia and Europe that crosses Istanbul's Bosphorus River by immersed tube

6

First breakthrough on the Belfast Sewer, in Northern Ireland

27 THE SÃO PAULO COLLAPSE

A unique metro accident in Brazil

An analysis of the events surrounding the 2007 collapse of the Pinheiros station cavern on the São Paulo Metro



32 PRODUCTS & SERVICES

35 MIXSHIELD TBM SPECIAL

The making of the Mixshield - Part 1

The Mixshield has revolutionised modern tunnel boring techniques. Part 1 of this article reviews the technology development

43

Dätwyler gaskets on segments for the Marmaray Tunnel

WATERPROOFING

43 KEEPING THE WATER OUT

Performing seals control hazard

The latest technology and products aimed at keeping tunnel structures dry are reviewed in *T&T*'s monthly round up

47 CLASSIFIED ADVERTISEMENTS

49 DATES & EVENTS



11

Gearing up for a start on the Jinping II HEP, in China





18,300 TUNNEL LINING SEGMENTS FOR 5,800 METERS OF TUNNELLING IN 15 MONTHS.

After 5.8 kilometers of tunnelling, the Herrenknecht S-333 broke through to its target shaft on March 6, 2008. The Single Shield TBM (diameter 11,835mm) had tunneled the twin tubes of the Mont Sion tunnel on the new section of the A41 highway in the French Alps within 15 months only. With high weekly tunnelling rates of up to 180 meters the jobsite team drove the Herrenknecht machine through the mountain. Difficult geological fault zones were safely mastered.

The project's challenging time schedule required more than a high performance TBM. Herrenknecht's tailor-made package delivered to the jobsite included the complete plant for the tunnel lining segments. 90 segments per day, 18,300 segments in total are an excellent reference for the new subsidiary Herrenknecht Formwork Technology GmbH established in 2007.

SAINT BLAISE | FRANCE

PROJECT DATA



S-333
Single Shield TBM
 Diameter: 11,835mm
 Driving power: 2,560kW
 Tunnel length: 2x 2,900m
 Geology: molasse

CONTRACTOR

Bouygues Travaux
 Public
 GFC Construction
 DTP Terrassement
 Colas
 Losinger Construction



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

www.herrenknecht.com



Let's get (geo)physical

Flicking through the articles in *T&T* this month, shows to a certain extent the degree to which the tunnelling industry can cope with fresh challenges in adverse situations. Installing yielding concrete elements within steel rib supports to deal with highly squeezing ground is well in effect at the St Martin La Porte access adit on the Lyon – Turin rail tunnel (p15). The re-designed lining method is now allowing steady advances to be made on a project that had been virtually stopped by bad ground.

Another example of ingenious engineering can be seen in Istanbul (p21), where a method of docking slurry TBMs with an immersed tube element is to be tried for only the second time ever (note: I believe this has been done once before in Hong Kong, but am happy to be corrected!). Also, and unusually for *T&T*, we have handed over five pages this month for part one of a two part article describing the history and future development of the Herrenknecht Mixshield TBM (p35). Without a doubt, the Mixshield has revolutionised the way tunnelling is carried out in difficult ground conditions.

So, with all of this modern technology available to us, and a host of engineers capable of using it, it's ironic to see that 'unforeseen ground conditions' have been put forward as largely responsible for the collapse of the Pinheiros Station shaft on São Paulo's Metro Line 4 last

year, that killed seven people (p27). Sadly, this tragic event will live on in the public's memory far more than the positive ones mentioned before it.

With all the technology and experience we have, our major nemesis is still the medium we work in. Extensive traditional site investigations are said to be overly costly and virtually physically impossible in some sub-urban construction projects resulting in a call for a costlier, deeper positioning for tunnel structures and stations in such areas. These additions in cost will only prove prohibitive in getting any underground urban projects built.

The expression 'unforeseen ground conditions' is so commonplace that maybe it's time to invest far more into a new type of technology to make it less 'unforeseen'. What happened to all the research we heard about a few years ago into 3D geophysical predictions of the ground? Has it really proved impossible to do? With all of our technological advances in other fields, I find it hard to believe we can't hone our understanding of geophysical modelling.

More reliable modern site investigation methods could not only go a long way to preventing such tragic incidents as the Pinheiros collapse, but actually make urban projects more financially viable, which for the industry can only be a good thing.

Tris Thomas



COMPANIES IN THIS ISSUE

Alpina	15, 17	Dogus	21	London & Continental	24	Porr	7
Alstom	21	E Phil & Sons	8	Lovat	6, 23	Rascor	46
Antea	17	Egis	15, 17	Lyon Turin Ferroviaire	15, 17	Razel	17
Asian Development Bank	6	EHDC	11	Malmö Citytunnel Group	8	Robbins	7, 11
Atlas Copco	32	Elkem	45	Marubeni	21	São Paulo Metro	29
Avrasyaconsult	21	Farrans	6	Max Bogl	7	Scandinavian Rock Group	46
Banverket	8	Flag	45	Minova Carbotech	43	Severn Trent Water	6
BASF	43, 46	Flexco	32	Morgan Est	6	Shenyang Heavy Machinery Group	10
Bauer	24	Gama	21	Mott MacDonald	24	Sika	43, 45, 46
Bilfinger Berger	8, 17	GIE Constructors	10	Murer	46	Strabag	12
Bouygues	10, 12	Global via Infraestructuras	12	NFM Technologies	10	Taisei	21
Brückner Grundbau	43	Granulats Rhone-Alpes	17	Nordic Development Fund	6	Tecinvest	43
Celtic Metro Group	12	Grupo Soares da Costa	12	Northern Heavy Industries	10	Terrasol	17
China Railway Tunnel Group	10	Herrenknecht	7, 8, 11, 35, 46	Nurol	21	Thames Water	6
Condat	23	Hitachi Zosen	23, 24	Obrascon Huarte Lain	12	Theodor Codes	46
Continental Group	46	Hochtief	46	OPC	23	Transit New Zealand	8
ContiTech	46	Impregilo	7	Orica	43	Travers Symonds	24
Council of Europe Development Bank	21	IPIT	29	Oriental Consultants	21	TunnelTec	10
CVA	27, 29	Japan International Cooperation Agency	6	Pacific Consultants	21	Vertex	46
Dätwyler	45, 46	JARTS	21	Parsons Brickerhoff	21	Vietnam Railway Corp	7
Davy Markham	11	JBIC	6, 21	Per Aarsleff	8	Wayss & Freytag	7, 35
Db Netz	7	Kimia	45	Phoenix	45, 46	Yuksel	21
				Pizzarotti	17	Züblin	46

Breakthrough in Belfast ...



Morgan Est/Farrans JV holes through on Belfast Sewer

The JV of Morgan Est and Farrans (Construction) as holed through on the first, and one of the longest, stretches of the Belfast sewer project with a 4.7m diameter Lovat mixed face EPBM.

Groundwater varied from 22m-31m above the tunnel invert and geology along the 1,290m long section mainly was comprised of

two glacial deposits, boulder clay and Malone Sands.

There were also significant areas of bedrock comprised of Sherwood Sandstone, Mercia Mudstone and Upper Permian marls, and the TBM also met vertical doleritic dykes of variable thickness.

Similar geology is expected for the 540 tonne EPBM along the



next section of the sewer, which is 2,200m long. In total, the JV will design, build, test and commission approximately 9.4km of tunnels of up to 4m i.d., and the project also includes pipejacks up to 1.8m diameter. The scheme also includes 27

shafts of 7.5m typical diameter and one of 40m diameter.

The client, Northern Ireland Water, is building the tunnel as part of a US\$200M upgrade of the city's 19th Century sewer system. The project is to be completed in 2009 (T&T, September 2006, p6).

... down for Ring Main

Preparations for the start of excavation of a 4.5km long extension to the London Ring Main are underway following the lowering of the Lovat 131 TBM at

the Stoke Newington shaft.

Contractor Morgan Est is building the tunnel for client Thames Water to link the Coppermills treatment works to supply the Ring Main. It will do so by linking up the existing mains at Stoke Newington and New River Head.

Geology along the route comprises London Clay and Thanet Sands. The 2.85m i.d. tunnel is to be built with precast bolted segmental lining with a secondary, insitu reinforced concrete layer. The alignment passes below tube lines, rail tunnels a canal tunnel and two major sewers.

The contract was awarded to Amec in January 2007, for commencement on site in the third quarter last year. Amec's tunnelling business was subsequently transferred with other assets when Morgan Est acquired a major part of the group last year. The job is still earmarked for completion in 2010 (T&T, February 2007, p6).

The extension, being built using the shield "Cleo", is part of the client's "Resilience Project" which will take the Ring Main's potable water supplies to parts of the city still served by old water mains.



Lovat TBM lowered for London Ring Main drive by Morgan Est

Nepal water tunnel set for go

Long delayed plans to build a 26km water diversion tunnel as part of Nepal's US\$317M Melamchi water transfer project are set to go-ahead after the Asian Development Bank (ADB) agreed to revised terms of the project.

The scheme has been deadlocked since 2000 in wrangles over aid financing. The ADB said the scheme looked set to proceed after financiers split it in two, one segment covering tunnel construction and the other involving water treatment facilities.

The tunnel will divert 170m litres per day from the Melamchi river to Kathmandu Valley to ease chronic water shortages.

The bank also dropped its requirement of a management company to oversee Nepal's water resources. UK water utility Severn Trent Water was initially chosen for the role, but the Nepalese Government refused to ratify the utility's appointment and the scheme foundered.

Commenting on the changes that have allowed the scheme to be resurrected, ADB official Leonardus Boenawan Sondjajago, said: 'While the need to address the water crisis is growing, the changing circumstances surrounding the project required adjustments in scope and implementation arrangements.'

Sondjajago heads up the project administration unit at the urban development division of the bank's South Asia department. He added: 'This project is the only realistic way to obtain a sustainable, long-term supply of drinking water for Kathmandu Valley.'

The ADB will lend US\$137M to the scheme while the Nepalese Government is to contribute US\$90M. The remaining US\$90M will be split among a raft of aid agencies comprising the Japan Bank for International Cooperation, the Japan International Cooperation Agency, the Nordic Development Fund and the Organization of Petroleum Exporting Countries' Fund for International Development.

Finnetunnel underway

Official launch of the first of Herrenknecht's two TBMs on the Finnetunnel twin rail link project in Germany was marked at the close of last month – slightly ahead of programme.

The start-up of the 10.82m diameter convertible, mixed mode machine by the Wayss & Freytagged JV will be followed shortly by its sister TBM. The first shield was initially due to commence excavation in July, the second TBM in December.

The machines will bore 4,600m lengths of tunnel with the rest of the 6.8km long drives constructed using the NATM technique.

Geology along the alignment comprises high groundwater head (up to 6 bar) where borehole drawdown will be used to enable the TBMs, in the latter part of the drives, to bore those sections in open mode. But, due to weathered sandstone with clay/silt, the groundwater cannot be lowered in the early stretch and the TBMs will operate in slurry mode.

Tunnel lining consists of 9.6m i.d. segmental rings (6+1), the rings being 2m long. Cross



Official launch of first at Finnetunnel, Germany

passages with airlocks are to be built every 100m.

The JV was awarded a US\$381M contract, with other consortium members including Max Bogl and two units of Porr.

Finnetunnel is being built as a key section of the 10.5km long

Erfurt to Leipzig/Halle twin track rail line.

The client, DB Netz, awarded

the contract in late 2006 and the link is due for completion in 2011 (T&T, September 2007, p10).

Jökulsá bore ends

The Robbins TBM's breakthrough last month on the Jökulsá branch tunnel marked the end of the widely varied excavation experience on the headrace and transfer tunnels of

the Kárahnjúkar hydropower project in Iceland.

Progress rates achieved with the 7.23m diameter TBM included 115.7m in 24 hours and 428.8m in the best week – both



Hai Van rail bore plan

Vietnam Railway Corporation (VRC) plans to build a US\$200M tunnel through the Hai Van Pass in the middle of the country as part of its five-year investment plan.

The rail company wants to build a 10km long twin-bore tunnel through the pass to cut journey times by two hours. Growing passenger and freight demand has forced the move following earlier tunnel upgrades.

The Hai Van Pass, which connects Da Nang on the coast of

central Vietnam with the province of Thua Thien-Hue, is a transportation bottleneck for train services between the north and south of the country.

VRC is using its infrastructure management board, based in Da Nang, to plan the new rail scheme.

In 2001, the company began construction work to upgrade four existing rail tunnels through Hai Van Pass. The volume of rail demand has quickly required additional capacity and led to the go-ahead for a new tunnel.

achieved early on the drive. The machine was launched in April 2007 and completed the 8.7km long bore in a year.

Geology along the route comprised basalt, pillow lava and moberg with UCS up to 300MPa. The excavation of the branch tunnel did not have the difficulties the TBM previously encountered when driving a 11.1km long stretch of the main headrace tunnel.

Two other Robbins TBMs were employed on the headrace excavation, one of which – "TBM1" – has been refurbished, enlarged from 7.6m to 9.7m, fitted

with 19" cutters and has started work on the 2.4km long adit for the Ceneri Base Tunnel, in Switzerland (T&T, March, p10). The other machine will work in China.

In total, contractor Impregilo used the three TBMs to excavate almost 50km of tunnel over four years. The power station is already being fed by the headrace tunnel, but is not at full power. Following the completion of floor concreting and walls being lined with mesh and shotcrete, the branch tunnel is due to convey additional water to the power plant by August.

Malmö tubes bored



Left: Segments during construction of the Malmö Citytunnel
Below: Final TBM breakthrough at Malmö C station



© K. Andersson

Excauation of the twin bore tunnels for the Malmö Citytunnel rail project was completed last month when the second 8.89m diameter TBM holed through after the final, 1.9km long drive.

The Herrenknecht machine, named "Katrin", was relaunched on the more difficult, final drive from Triangeln station to Malmö Central – or, Malmö C – in late December 2007. In total, the TBM excavated just over 4.6km in two drives.

Katrin was first launched at Holma in early 2007. The contractor, Malmö Citytunnel Group (MCG), completed the 2.7km long drive, to Triangeln, in September last year after which the TBM was pulled through the station and overhauled in preparation for relaunch to Malmö C.

Geology along the route comprised limestone and the drive at depths of 20m-25m was against groundwater almost 20m above the tunnel invert. The last drive was below more residential areas and

MCG had to deal with a number of tighter turns in the alignment. Before relaunch, the client Banverket said that on the first run the public had detected vibrations as structure-borne sound as the TBM passed below.

Katrin was the second of two TBMs to drive the twin tubes, the first – "Anna" – which it followed mostly a month and some 500m-600m behind. Anna was launched in November 2006 and holed through at Malmö C in late March (T&T, April, p7). The bores are lined with 7.9m i.d. segments (7+1) in 1.8m long rings.

MCG is building the Citytunnel project under a US\$325M (2001 prices) design and build contract. Members of the JV include Bilfinger Berger, Per Aarsleff and E Phil & Sons. Banverket wants the full, US\$1.3B (2001 prices), scheme finished by 2011 which now looks more promising. It had initially anticipated TBM excavation to be completed by mid-year or in the third quarter.

© The Scandinavian Insider

NZ looks to Waterview link

Work could start in late 2009 on a US\$1.5bn "Waterview Connection" road tunnel in Auckland, New Zealand, after the Government approved the link.

The 3.2km long twin bore tunnel is to be excavated by TBM at a depth of approximately 40m and will have concrete segmental lining.

The project, being developed by Transit New Zealand, will link Mount Roskill and the Northwestern Motorway via portals at Hendon Park and Waterview Park. The developer said the Waterview Connection, which is to be 5km

long in total, might be procured by public-private partnership (PPP) but no decision has been taken on whether the tunnel should be a tolled transport link.

The scheme was unveiled by two government officials, finance minister Michael Cullen and transport minister Annette King. They said that a six-member steering group headed by independent chairman and former Chief Ombudsman Sir Brian Elworthy, would investigate the feasibility of developing the scheme under a PPP arrangement.

The steering group, whose members also include Stephen Selwood, head of the New Zealand Council for Infrastructure Development, and Phil O'Reilly of Business New Zealand, is due to submit its report to the finance and transport ministers next month.

Transit New Zealand said the link is planned for completion in 2015 and would then complete Auckland's 48km long Western ring route. However, the project has run into opposition from both pro- and anti-government political parties.

Green Party legislator, Keith

Locke, claimed the scheme showed 'muddled thinking' by the Government on transport. He added that while the recently inaugurated North Shore Busway got 'Aucklanders out of their cars', the proposed new project would only serve to 'encourage them to hop back-in'.

The pro-government party, United Future, called the plans to only small steps towards PPP, six years after the procurement legislation was passed. Support, however, came from the New Zealand Contractors Federation.



Rock science supports project superiority



Application expertise gets your business rolling

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



CRTG holes through with NFM's second TBM at Wuhan, China

Wuhan done, Hangzhou next

The second drive on the Wuhan twin-tube road tunnel was completed late last month by China Railway Tunnel Group (CRTG) which is to take both of the NFM Technologies' shields for a project in Hangzhou.

At Wuhan, the 11.38m diameter slurry TBMs bored 2.7km long tubes below the Yangtze river. The city is divided by the Yangtze and Han rivers, and the bored tubes are part of larger, 3.63km long twin tunnels that will be a key section in a new cross city link.

Geology comprised silt and sand with clay and large boulders. Buckets and face scrapers were supplied by TunnelTec. The second TBM was launched just over a year ago, a few months after the first machine, which

completed its drive in January. Originally, it was expected that excavation of the twin bored tunnels would be over by the end of last year.

CRTG now plans to reuse both machines for drives of 1,750m long each on a project in Hangzhou. The TBMs are to be refurbished and their diameter increased to 11.65m for the project.

NFM has also seen orders in China for a number of new machines for mostly metro but also a few water projects (*T&T*, March, p7). The company is majority owned by the Chinese group Northern Heavy Industries (NHI), which also holds NFM's partners on many TBM contracts, Shenyang Heavy Machinery Group (SHMG).

Mont Sion drives finished

TBM excavation was recently completed for the twin drives below Mont Sion, in south west France, for the A41 highway extension. A single shield of 11.94m diameter was used to bore both tubes for the fast-track construction programme being executed by a Bouygues-led JV, called GIE Constructeurs A41.

The JV excavated the tunnels through molasse deposits with little groundwater under Mont Sion. Both tubes are approximately 3km long and 10.7m i.d. built of concrete segments (5+1) in 2m long rings.

Excavation began in October 2006 and the first tube had been completed by June 2007 – after

which the JV took the cutterhead in its entirety back for reassembly and relaunch last September.

Following the completion of the main excavation with the Herrenknecht TBM (S-333), in March, work is currently underway on eight connecting passages (four vehicular, four pedestrian). There will also be 20 emergency and 15 fire equipment recesses.

The project, being built for a 55-year concession, is designed by a JV of Bouygues and SETEC. The entire construction schedule is 29 months, concurrent engineering has been key to pushing ahead the pace, and the road in the French Alps is due to be opened just before the end of the year.



In for Jinping II hydro ...

Preparations to begin tunnel excavation at the Jinping II hydropower scheme, in China, has reached the start-up stage just over a year after the contracts were placed with Robbins and Herrenknecht for two 12.43m diameter TBMs.

The hard rock machines will be used to drive two of the four parallel headrace tunnels for the project. Assembly of the TBMs has been in chambers excavated by drill and blast.

Drill and blast is also being used for the two other bores, also 16.7km long. All of the headrace tunnels – spaced 60m apart – are to be completed by 2010.

To tackle the drives, Robbins has supplied a main beam TBM for which UK-based Davy Markham manufactured the 320 tonne cutterhead that will be fitted with 19" backloading cutters.

Herrenknecht has built a hard rock gripper with cutterhead power of 4900kW and torque of 19,750kNm.

The client, Ertan Hydropower Development Co Ltd (EHDC), ordered the TBMs. It noted previously that there were critical geotechnical issues in developing such long tunnels. Key issues identified include high rock stress and bursts, karstic features, groundwater, high ground temperatures and hazardous gases.

EHDC undertook an exploratory programme to help minimise the excavation difficulties, opening up 5km of tunnels including the access



Herrenknecht's TBM for the Jinping II project, China

tube. Geology along the alignments are mostly comprised of limestone and marble with some sandstone and schist. The rock strengths are up to 80MPa, overburden is up to 2500m, and there are fracture and fault zones.

Jinping II is the latest project in a cascade hydropower development and the tunnels are a key feature in the layout, cutting across a long river bend to exploit the difference in water levels. EHDC expects the 4,800MW power plant, in Sichuan province, to be commissioned over 2012-14.

Davy Markham made cutterhead for Robbins' Jinping II TBM



... out for Po Shan Rd drainage

Work is underway to bore arrays of drainage holes through the concrete lining in two tunnels following the completion of short-mode TBM excavation at the tight, Po Shan Road site in Hong Kong.

Excavation of the drainage tunnels was undertaken using a Robbins main beam TBM built for partial retrieval and relaunch, plus a bespoke short-run mucking out system. The short-mode system created for the job completed a total of 459m of tunnel to open an access tube from which the two

drainage tunnels were driven.

The China State/China Railway JV undertaking the project was restricted in tunnelling activities to eight hours per day, leaving Robbins to perform overnight routine maintenance on the 3.5m diameter shield and back-up system.

A new type of cutterhead that does not rely on welding was developed for the project, and utilised a 250mm thick front plate with a cone and flange behind. The tools include 17" front-load cutters and buckets. The cutters housings and muck buckets were

removable to ease the shield back down the tunnel for relaunch.

Geology in the hillside comprised Grade 1 granite and tuff of UCS 200MPa-300MPa. A short-run mucking out system was employed, which took spoil by conveyor to a holding wagon behind the TBM from where its own, bottom, conveyor fed a muck car pulled by a loco. Main excavation was completed in mid-March.

The drainage tunnels – 244m and 165m long, respectively – were lined with bolts, mesh, shotcrete, ring beams. The final



lining was a 200mm thick concrete shell, through which dozens of drainage holes are being bored. The project is a key part of a local slope stabilisation scheme in the expensive residential area in Hong Kong Island's Wan Chai section (T&T, June 2007, p6).

Prequal JVs weigh Dublin Metro North

Four prequalified joint ventures have been issued with tender documents for the public-private partnership (PPP) procurement of the Metro North tram link in Dublin.

The project will involve construction of some twin tunnels of 6.7m diameter, spaced approx 7m apart, mostly in the centre of Dublin but also at the airport. The tunnels will be at least 20m deep, resulting in cover of 15m. There will also be a section of cut and cover tunnel construction. Boreholes of 20m-55m depth are to be sunk.

The four JVs are: Cathro; Celtic Metro Group; Dublin Express Link; and, MetroExpress.

The Cathro JV includes Strabag, and the Celtic Metro Group contains Grupo Soares da Costa and Obrascon Huarte Lain. In the other JVs, Bouygues is part of Dublin Express Link, and

Global via Infraestructuras is a member of MetroExpress.

Under the 30 year-PPP concession, the winning bidder will design, finance, build and operate the 17km long tram link that will run north-south in the city. The project is being developed by Railway Procurement Agency Ireland.

Tenders for the concession are sought towards the end of this year with best, and final, offers then required after the legal rights for the scheme, via the railway order, are given in 2009. The client expects to submit its application for the railway order shortly.

The route will run from Lessenhall in the north of the city and on to the airport and then the heart of Dublin, to Parnell Square and O'Connell Bridge. On the south side of the river Liffey then Metro North route will link

Bids for HK's Harbour Area sewer

A call has been issued for contractors to prequalify for two sewer tunnel contracts with a combined length of almost 20km as part of the second stage of Hong Kong's Harbour Area Treatment Scheme.

The deadline for submissions to Hong Kong's Drainage Services Dept is 27 June. Bidders must have experience of major tunnelling with pre-grouting as the main method to control groundwater at pressures of at least 7 bar. The tunnels will be driven through granitic and volcanic rocks with excavated spans of 4m-5.5m.

The client intends to invite prequalified contractors to bid for the contracts in September. Construction is scheduled to start early 2009 for completion by mid-2013.

In Contract DC/2007/23 the client plans to have approximately 12km of sewer of up at depths of 140m-160m below sea level. The sewer will be built with eight shafts of various diameters.

The second contract – DC/2007/24 – will have a shorter, shallower tunnel and of smaller diameter. The Drainage Services Dept plans a sewer of approximately 7.5km long at depths of 70m-120m below sea level.

Seven shafts are to be built for this section of sewer.

with existing lines at St Stephen's Green.

O'Connell Bridge station will be mined in rock beneath the river Liffey, breaking out from the excavated running tunnels. Parnell Square station will be excavated by top-down box construction.

There has not been a decision yet on whether 24 hour working will be allowed for the construction

phase of the project. Less noise disturbance is anticipated as the tunnels will be smaller than those for the Port Tunnel and spoil will be about a quarter of that produced from that scheme.

The project is expected to carry approximately 34M passengers per year, and is part of the government's Transport 21 investment programme.

More Erfurt rail tunnels

Germany's rail infrastructure operator Deutsche Bahn (DB Netz) has called for tenders by mid-June to build twin rail tunnels near Erfurt.

DB Netz is seeking bids by 12 June for construction of two parallel rail tunnels between Ebensfeld and Erfurt. The validity of the tenders is to mid-January 2009.

Construction work on the contract, which is principally for excavation of twin 7.4km drives, is to commence in May 2009.

The client plans for the rail link to be completed by the end of the third quarter of 2012.

Not far from the intended project site, DB Netz witnessed last month the commencement of TBM excavation on the Finnetunnel project, between Erfurt and Leipzig/Halle (see p7).

ITA to appoint Exec Director, seeks applicants

The International Tunnelling and Underground Space Association (ITA) is recruiting an Executive Director to manage the organisation and play a major role in contacts with other agencies and in events.

With ultimate responsibility to the Executive Council and General Assembly, the Executive Director will manage the financial and organisational matters of the ITA. The post-holder will need to work closely with the ITA president, in particular, but also with the organisation's treasurer, secretary general and auditor as well as the staff of the secretariat based in Lausanne, Switzerland.

Consequently, the ITA is looking for a senior individual educated with experience in management, finance, leadership, marketing, public relations and communication – for the latter points, preferably also a familiarity with non-for-profit organisations (which, as well as being a non-governmental organisation, is the status of ITA).

Candidates must also have attained at least Bachelor degree level in relevant fields and be able to work well in a bilingual organisation (English and French). They must also have a scientific/engineering background and familiarity with the tunnelling industry.

ITA wants the Executive Director to be able to

attend headquarters in Lausanne on a regular basis as well as travel internationally on behalf of the organisation. Travel would be needed for promotion of ITA, its aims and strategy, events, and work with member and sister organisations, the UN and EU and other non-governmental organisations.

With respect to events, ITA wants the Executive Director to arrange and promote meetings, seminars, training sessions and conferences, and participate in them then follow-up. For the annual World Tunnel Congress, the organisation wishes the post-holder to liaise with and supervise the host nations.

In addition, the Executive Director would manage promotion, public relations and publishing activities, including through print and electronic means.

As a newly established position, the post of Executive Director of ITA is to be filled with effect from 1 January 2009. Depending on candidates, the position could be up to full-time. Deadline for applications is the end of next month – 30 June.

For any questions regarding this post, ITA requests that potential candidates contact the Secretariat with CV, Letter, references and a statement of suitability, by email, at: secretariat@ita-aites.org

normet

FOR TOUGH JOBS

I ♥ tunnelling & mining!*

* It's for my future

- More than 7000 vehicles on the market
- More than 60 countries being served
- More than 45 years of experience



www.normet.com

Tell us your needs!

Normet International Ltd • Neuhofstrasse 3 D • CH-6340 Baar • Switzerland • **T** +41 (0)41 768 52 00 • **F** +41 (0)41 768 52 11

Normet Asia Pacific Pty Ltd • 16 D Ashwin Parade • Torrensville • (PO Box 772, Torrensville Plaza) • SA 5031 • Australia • **T** +61 8 8152 7700 • **F** +61 8 8152 06 67

Normet Americas, Inc. • 5775 Waterford, Suite 110, Blue Lagoon Drive • Miami, Florida 33126 • USA • **T** +1 786 433 11 04 • **F** +1 786 433 11 08

Normet Chile Ltda • Panamericana Norte 18900, Lampa, Santiago • Chile • **T** +56 (2)7387585 • **F** +56 (2)7387619

Norservice LLP • Ul. Gagarina 37, kv. 22 • 100604 Zhezkazgan • Rep. of Kazakhstan • **T** +7 7102 764 922

Normet Group • Ahmolantie 6 • FI-74510 Iisalmi • Finland • **T** +358 (0)17 83241 • **F** +358 (0)17 823 606

info@normet.fi • www.normet.fi



| OFFERING YOU OUR FINEST MODELS FOR OVER 20 YEARS |

As the designer and creator of high-performance equipment, NFM Technologies is one of the world's leading manufacturers of tunnel-boring machines. For 20 years now, the company has been successfully rising to the most intricate of challenges.



Here are just a few of our achievements: 5,100 m excavated with no changeover in cutting tools while boring under the Yangtze River in China; worldwide record holder for progressing 1,030 m in one month in pressurised mode for the Madrid metro system; over 40 km of gallery completed in hard rock using the same machine... the list goes on and on.

All these examples and more speak volumes about the strength, the performance and the reliability of our tunnel borers. Covering all types of geological conditions and capable of diameters of up to 15 m, NFM Technologies' range of machines offers tailor-made solutions for all your underground structures.



Rail | Road | Water

www.nfm-technologies.com



NHI GROUP

Creator of underground spaces



Above: View in the background of the support system initially adopted which underwent convergences up to 2m and later needed to be re-profiled

Saint Martin squeeze

G Barla, Politecnico di Torino, M Rettighieri and Fournier, of LTF, A Fava, of Alpina, and J Triclot, of Egis, describe the current status of the Saint Martin Access Adit and the related research studies on squeezing rock being undertaken

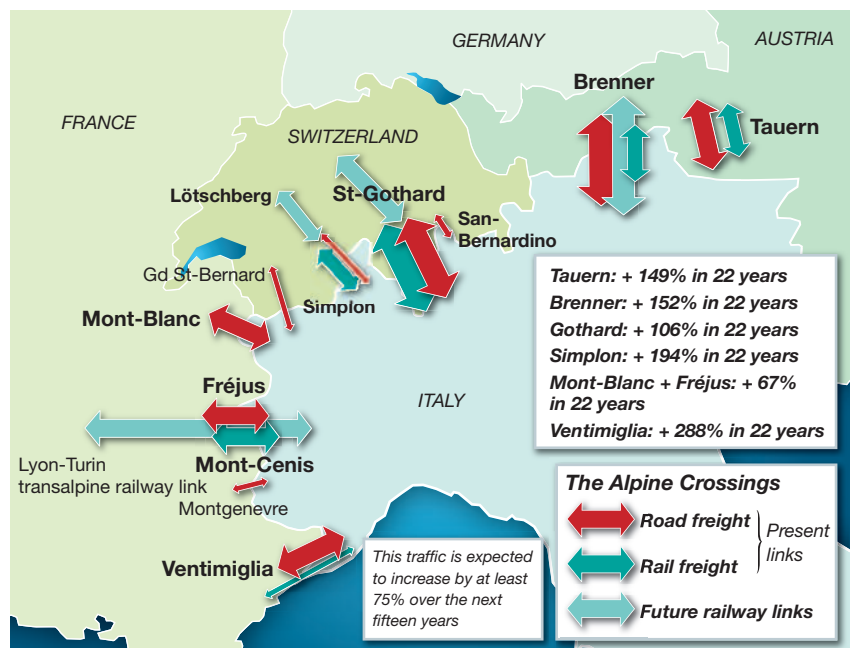
The Saint Martin La Porte access adit is a vital part of the early works for the US\$11.7bn, 53km long Lyon-Turin Base Tunnel. It is currently being successfully excavated using a novel method through ground that at times exhibits extremely severe squeezing conditions^[1]. An essential feature of this method is a two-stage excavation sequence with the installation, in the second stage, of a shotcrete lining which incorporates steel ribs with sliding connections and yielding concrete elements in longitudinal slots.

This method proved successful in permitting excavation, with construction proceeding slowly, where the cross section and stabilisation methods previously adopted failed so dramatically that it brought face advance almost to a standstill.

Lyon-Turin high-speed rail link

The Lyon-Turin high-speed rail link is at the centre of the axes linking the North and South, and East and West Europe (figure 1).

The 53km long, parallel tube Base Tunnel is to be excavated between the portals in Italy and France (figure 2). At present two access adits (La Praz and Saint Martin La Porte) are being excavated and one adit (Modane) is complete. They are essential for understanding the geological, geomechanical and hydro-geological conditions along the alignment and for the selection of the excavation method to be used for the Base Tunnel. They will also provide multiple faces for construction, and be used for ventilation access for maintenance and rescue teams if necessary.



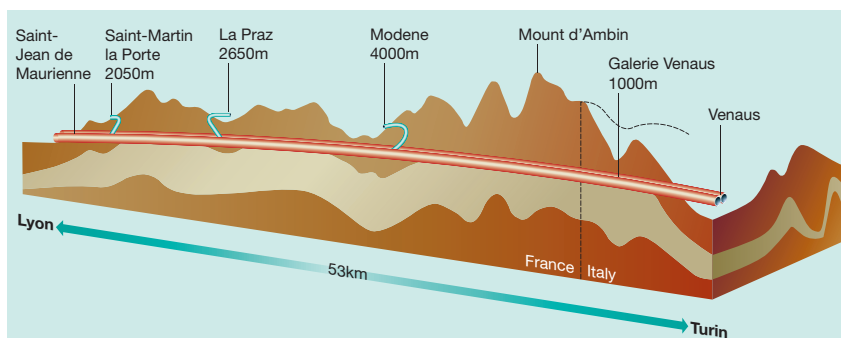
Above: Fig 1 - The Lyon-Turin high-speed railway link responds to the increasing traffic through the Alpine crossings

Saint Martin La Porte access adit

The Saint Martin La Porte access adit is being excavated in the Carboniferous Formation, "Zone Houillère Briançonnaise-Unité des Encombres" which is composed of black schists (45-55%), sandstones (40-50%), coal (5%), clay-like shales and

cataclastic rocks. A characteristic feature of the ground observed at the face is the highly heterogeneous, disrupted and fractured conditions of the rock mass that exhibits severe squeezing problems. The formation is often affected by faulting resulting in a degradation of the rock mass conditions.

The overburden along the tunnel ranges from 300-600m although excavation takes place in essentially dry conditions. In order to assess the rock mass quality during excavation, detailed mapping of the geological conditions at the face was undertaken. This provides information to evaluate the percent distribution of "strong" (sandstones and schists) and "weak" (coal and clay-like shales) rocks at the face. It has been found that the "weak" rocks are the main cause of the squeezing problems associated with the Carboniferous zone, having an estimated length of more than 600m.



Above: Fig 2 - The Base Tunnel between Saint-Jean de Maurienne and Venaus including the three access adits



BORING THROUGH FUTURE

TBM Systems Manufacturers & Tunnel Builders

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

TBM systems manufacture

Tunnel Builders

TBM systems overhauling and rental

TBM operation services and supervision

Rolling stock

Segment moulds



www.selitunnel.com - www.selitecnologie.com



Above left: Installation of the highly deformable concrete elements in stage 2

Above right: Excavation of the invert and placement of steel ribs in stage 2

Excavation support system

Several support systems were used in the Carboniferous zone. It soon became apparent that stiff support would not work in the squeezing conditions. The design concept finally chosen allowed the support to yield while using full-face excavation with systematic face reinforcement by fibre-glass dowels. The support system initially implemented consisted of yielding steel ribs with sliding joints (TH, Toussaint-Heintzmann type), anchors and a thin shotcrete layer in a horseshoe profile (P7.3). These sections of the tunnel underwent very large deformations with convergences up to 2m and later needed to be re-profiled.

To improve the working conditions and to

control deformations, a novel support system was implemented with a near circular cross section (DSM) (figure 3).

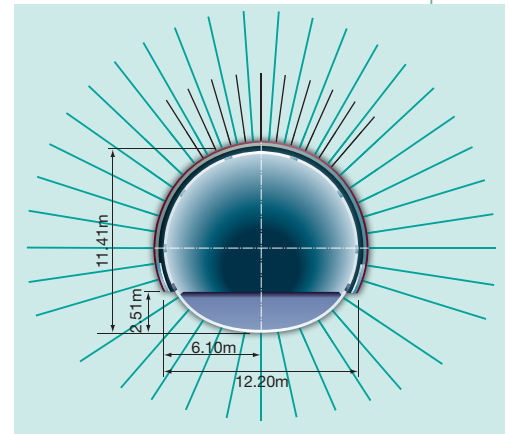
Stage 0: face pre-reinforcement, including a ring of grouted fibre-glass dowels around the opening perimeter, designed to reinforce the rock mass over a 2-3m thickness.

Stage 1: mechanical excavation carried out in 1m steps, with installation of 8m long un-tensioned rock anchors along the perimeter, yielding steel ribs with sliding joints (TH type), and 100mm of shotcrete. The tunnel is opened in the upper cross section to allow for a 600mm convergence.

Stage 2: the tunnel is opened to the full circular section 15-25m from the face, with 200mm shotcrete lining applied, and yielding steel ribs with sliding joints (TH type) with 9 longitudinal slots (one in the invert) fitted with highly deformable concrete elements. The tunnel is allowed to deform so as to develop a maximum convergence that should not exceed 400mm.

Stage 3: installation of a coffered concrete ring 80m from the face.

The deformable elements are installed in slots in the shotcrete lining between TH type steel ribs^[2] allowing controlled deformations to take place. At Saint Martin each deformable element has a beam shape (height 400mm, length 800mm, and thickness 200mm) designed to yield at approximately 40% strain, with a yield stress chosen to be 8.5MPa. It is composed of cement, steel fibres and hollow glass particles. The glass particles increase the void fraction of the mixture and collapse at a



Above: Fig 3 - Tunnel cross section showing the new excavation support system (DSM) adopted between chainages 1325 and 1700m

predetermined compressive stress. The yielding strength depends on the composition of the mixture.

Controlled response

Systematic monitoring of convergence is underway along the tunnel where the support system described is being adopted systematically. Convergences are measured by means of optical targets placed along the tunnel perimeter. A number of special sections have been equipped with multi-position borehole extensometers and strain meters located across the deformable elements. Extrusometer monitoring has been used to measure the longitudinal displacement ahead of the tunnel face. In addition, the strain level in the primary lining

Below: Fig 4a (left) - Deformations along arrays 1-3, 3-5 and 1-5 at 15m from the face in stage 1. Fig 4b (right) - Convergences at 30, 80 and 120 days after excavation with stage 2 installed

FACT FILE

Saint Martin La Porte Adit Fact File

Client – LTF (Lyon Turin Ferroviare SAS)

Contractor – Razel/Pizzarotti/Bilfinger Berger/Granulats Rhone-Alpes

Contractor's Consultant – Terrasol

Engineer – Egis Tunnels/Alpina/Antea

Engineer's Consultant – G Barla, Politecnico di Torino

Adit Cost – US\$231M

Adit length – 2280m

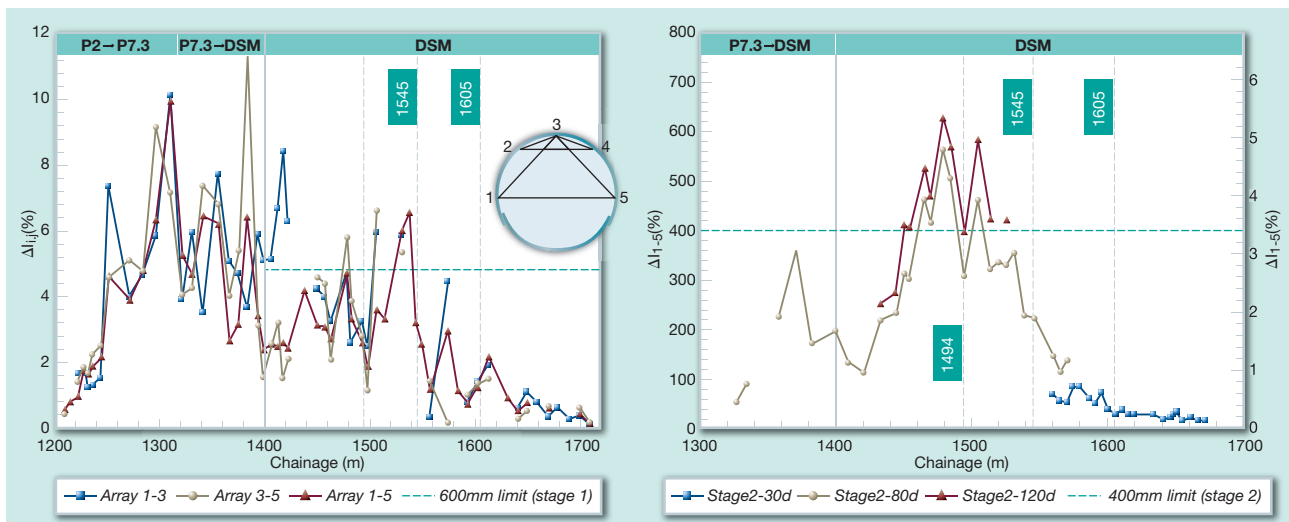
Adit section – 100m² (approx)

Construction method – 780m D&B, then pick hammer

Construction start – July 2003

Construction finish – Mid 2009

Current Progress (May 2008) – 1839m



has been monitored.

To understand the tunnel response, consider figure 4a, which shows the convergences measured along arrays 1-3, 3-5 and 1-5 (Δl_{i-j}) between chainage 1200m and 1700m, with the tunnel face being 15m ahead of the monitoring section. Up to chainage 1400m, the tunnel has been excavated using the P7.3 system; thereafter, the new DSM system, as described in figure 3, has been used systematically. Also illustrated in figure 4b, the tunnel “deformation” (i.e. convergence divided by the length of each array measured at the time of installation of the optical targets) that has occurred along the same tunnel length. It is relevant to point out that three steps of face advance shown in the same figure took place as follows: at chainage 1494m, for 18 days due to the 2006 Christmas holidays; at chainage 1545m, for 28 days, in relation to the tendering procedure that took place between April and May 2007; at chainage 1605m, for 14 days, for the excavation of a side drift at chainage 1488m.

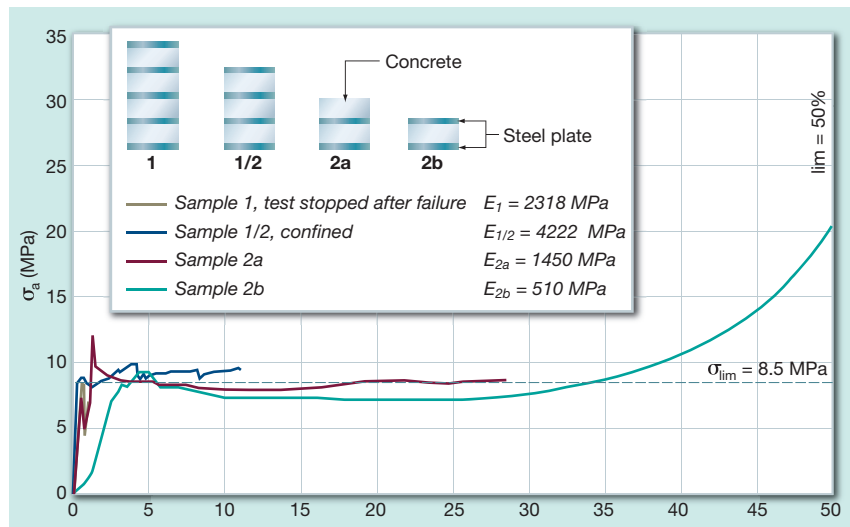
Additional observations can be made:

1) Large deformations are associated with cross section P7.3 between chainages 1200 and 1400m; with cross section DSM the convergences in phase 1 are mostly smaller with tunnel strain never exceeding 6-7%

2) The 600mm allowed convergence with cross section DSM has been exceeded locally (e.g., between chainages 1525 and 1550m where the rock mass quality was very poor) and required re-profiling of the tunnel cross section before installing the composite lining adopted in phase 2

3) The tunnel deformation associated with cross section P7.3 appears to be rather different in one section with respect to the neighbouring one, which generally is not the case for cross section DSM.

It is also important to consider the tunnel convergence versus time in stage 2 depicted



Above: Fig 5 - The characteristic curve obtained under uniaxial loading of the deformable element in the laboratory.

in figure 4b. This behaviour occurs at a significant distance from the advancing face and when the yielding support has been active for a certain time duration and the final concrete lining has not yet been installed. The diagram is for 80 and 120 days following excavation of the monitored section. It is noted that between chainage 1450 and 1525m, the tunnel cross section experienced deformations along array 1-5 in excess of that theoretically allowed (400mm). In such a case the yielding elements on the right wall (looking at the tunnel face) attained the allowed 40% limit strain (figure 5) so that visible overstressing occurred in them, which did not seem to be an issue because no difficulty was encountered before installing the final lining.

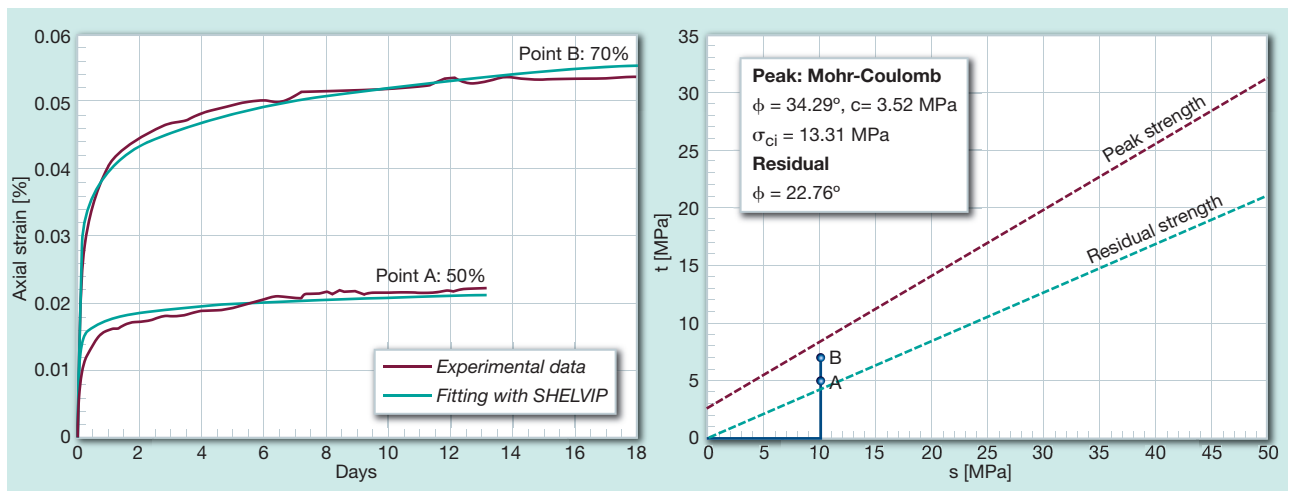
Innovative developments

The use of the deformable element with the DSM excavation-support system went through a learning process, which resulted in its careful installation having no adverse impact on the overall advance cycle. To underline the role of such an element incorporated within the primary lining, it is of interest to show in Figure 5 the characteristic curve of the deformable element obtained in

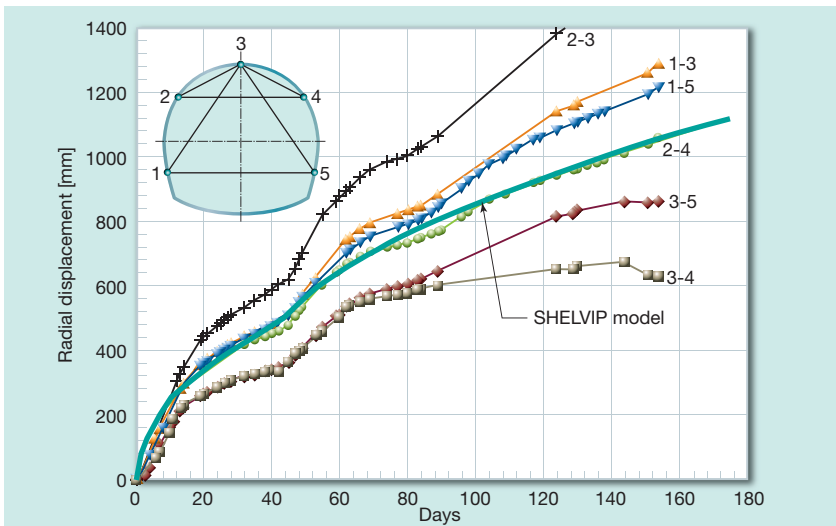
the laboratory. It is clear that as the yield stress is reached the element becomes plastic and the stress in it remains equal to 8.5MPa. Actually, the element incorporated in the lining is capable of shortening under a nearly constant tangential stress, while it applies to the surrounding rock, which is squeezing, a non-zero radial stress. It is this radial stress that is important in controlling the rate of deformation in the tunnel.

Squeezing is time dependent. Thus, under the most severe squeezing in the Saint Martin access adit, an appropriate representation of the tunnel response can only be obtained by using a behavioural model that may account for time dependence. This originates from the fact that time dependent deformations are observed whenever face advancement is stopped and these are likely to take place during excavation, when it is difficult to distinguish “face effect” from “time effect”.

Based on triaxial creep tests performed in the laboratory on coal samples taken from the tunnel face and from borehole drilling, a Stress Hardening ELastic Viscous Plastic model (SHELVIP) has been derived. According to such a model, the time-independent plastic strains develop only



Above: Fig 6 - Comparison of predicted (SHELVIP model) and measured behaviour in laboratory creep tests on coal samples



Above: Fig 7 - Comparison of predicted (SHELVIP model) and observed behaviour in the Saint Martin access adit during face advance. Monitoring section at chainage 1311m, with the old excavation-support system adopted (P7.3)

when the stress point reaches the plastic yield surface. The viscoplastic strain rates develop only if the effective stress state exceeds a given viscoplastic yield surface. The SHELVIP model is shown to describe well the results of creep tests of coal samples in the laboratory (figure 6). The same model can also reproduce the time dependent response of the tunnel during excavation^[3, 4] (figure 7). Note that the results presented are for the tunnel cross

section at chainage 1311m (P7.3), which experienced very large deformations when the excavation-support system adopted was that used prior to the one finally adopted.

Conclusions

Tunnelling in squeezing conditions is very demanding due to the difficulty in making reliable predictions at the design stage.

The system adopted in the Saint Martin La Porte access adit proved effective in

coping with this. A number of factors have been essential: teamwork; attention to the understanding the geological and geomechanical conditions to the readiness in adapting the excavation-support system to such conditions; the attention posed to observation and monitoring during face advance; and the conviction that the observed performance may allow, through a reliable model of behaviour for the rock, reliable predictions of tunnel response. T&T

REFERENCES

1. G Barla, 2002. Tunnelling under squeezing rock conditions, Advances in Geotechnical Engineering and Tunnelling
2. L Cantieni, G Anagnostou, 2007. On the variability of squeezing in tunnelling. 11th Congress of the International Society for Rock Mechanics.
3. D Debernardi. Viscoplastic behaviour and design of tunnels. PhD Thesis under preparation.
4. G Barla, M Bonini, D Debernardi, 2008. Time dependent deformations in squeezing tunnels, 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG).

When you bring together a world leading chemical company and one of the cornerstones of concrete pumping machinery you know good things are coming your way. Sika and Putzmeister engineer produce and distribute shotcreting machinery with state of the art technology in a wide range of sizes and configurations to meet even the most demanding circumstances. More than 140 years of combined history placed at your service.

We build from experience

Putzmeister

www.putzmeister.es/sprayedconcrete · + 34 91 428 80 23

Sika **PM**
Putzmeister

Experts on Sprayed Concrete

Integrated Alarm Warning Station

When it comes to keeping an eye on things our sensor station has **no equal** in its choice of input/output signals and direct power-up options to satisfy most tunnel applications.

Trox Limited. Newby Road, Hazel Grove, Stockport, Cheshire SK7 5DY UK
t. +44 (0)161 483 1435 e. sales@trolex.com

SENTRO 8

Integrated Gas Detection System

TX9165 TX9166



when you
need to
monitor
everything
around you
we only
have one
serious
rival!



- Up to six integral gas sensing modules
- Auxiliary 4..20mA sensor input channels
- High definition graphical display
- Configurable audio/visual alarms
- Configurable output control relays
- MODBUS datacomms for SCADA compatibility
- Data logging
- Built to withstand adversity

environmental
safety
monitoring

machine condition
monitoring

DATACOMMS

RS485 datacomms can be transmitted by 32 sensor stations on a single cable, communicating with a central PC.



www.trox.com

Trox supports the RSPB, wildlife and the environment



Right: Fig 1 - Plan map of the Bosphorus crossing alignment

Daniel Horgan and Douglas Madsen of Parsons Brinckerhoff presented a review of the Bosphorus Crossing project at the March meeting of the British Tunnelling Society

The construction of the underground and undersea crossing of the Bosphorus faces a diverse range of challenges from the excavation and preservation of archeological treasures from one of Europe's oldest civilisations to designing and constructing the deepest immersed tube tunnel in the busiest and narrowest shipping lane in the world in accordance with the highest international earthquake standards (figure 1).

The client for this impressive undertaking is the Department of Transport Turkey (DLH) supported by the Engineer, Avrasyaconsult, which is a consortium led by Pacific Consultants International and including, Yuksel Proje, Parsons Brinckerhoff, JARTS and Oriental Consultants.

Using FIDIC two party contracts with Avrasyaconsult acting as the Employer's Representative, the work is let in three design-and-build contracts. BC1 covers the 14km of two-track bored, immersed tube and cut and cover tunnels and was awarded to the Japanese and Turkish joint venture of Taisei, Gama & Nuro. CR1 covers all infrastructure and tracks on the 62km of three-track surface alignment, including all systems, surface stations, control centre and maintenance facilities; it was awarded to the French, Turkish and Japanese joint venture of Alstom, Dogus & Marubeni. CR2 covers all rolling stock and will be awarded this year.

Finance for the US\$3bn project is provided by the Japanese Bank for International Co-operation, the European Investment Bank and the Council of Europe Development Bank. The construction programme runs from 2004 to 2011.

Scope

The project scope includes 76km of triple track, the third track being for inter-city and freight; 3 depots; 2 workshops; an operations control centre and 44 ten-car passenger trains. The tunnels comprise 1.4km of immersed tube tunnel up to 58m deep, 9.8km of twin bored tunnel and 2.4km of cut & cover tunnel. There are three large

Crossing the Bosphorus and beyond

underground stations and 37 surface stations. All tunnels and stations are designed to remain operational after an earthquake of 7.5 moment magnitude.

The installed systems include ventilation designed for a 100MW freight train fire, probably the largest in the world, a 25kv AC traction power system and the newest signaling and communication systems.

The railway will run 3,500 person capacity trains and operate with a moving block signalling system. Step-free access to stations and trains will be provided. The track will comprise continuously welded rail and the systems have been designed in accordance with NFPA 130.

Archaeology

Istanbul was founded in about 658 B.C. by a Greek expedition and was named Byzantium after the leader of the colony, Byza. The city was renamed Constantinople after the Emperor Constantine following the Roman conquest in about 330 A.D. It subsequently became the capital of the Eastern Roman Empire. In 1453, the city was conquered by the Ottoman Empire, but its name was not changed officially to Istanbul until 1930.

Consequently the city is the site of numerous historic buildings, ruins and other

artifacts of Ottoman, Byzantine, Roman and Greek civilisations. Project excavations have exposed ten sunken boats, ancient walls and pottery; chapels, cisterns, baths and villages have been discovered; and the port of Constantinople, also named the 'Eleutherios harbour' in historical records, one of the busiest ports in Byzantium, has been uncovered. archeological investigations at Yenikapi station involve 130,000m³ of hand-excavated spoil.

Geology

The geology of the tunnel alignments includes interbedded clay and limestone, water-bearing sand and stiff to hard clay between Yedikule and Yenikapi cut and cover stations. The remainder of the bored tunnels will be driven in the Trachya Formation, which comprises interbedded mudstones & sandstones with unconfined compressive strengths between 20 and 100MPa intruded by dolerite dykes of up to 200MPa. The sea bed in the Bosphorus comprises soft marine sediments (figure 2).

Ground investigation was carried out in several phases. A design phase in 1985 to 1987 comprised 20 marine boreholes, 37 land boreholes, penetrometer testing, geophysics and bathymetric surveys.

Your goal is our goal.



Telescope Shield Tunnel Boring Machine for Water Supply and Water Diversion Project.

Canal de Navarra | Spain



Open Type Gripper Tunnel Boring Machine for Hydro Electric Power Project.

Ermenek Hepp | Turkey



Earth Pressure Balance (EPB) Shield Tunnel Boring Machine for Railway Project.

Ferroviano di Castellanza | Italy



With its many years of international experience, WIRTH offers tunnel boring machines for all types of soil, in all diameters and for all applications. These application areas include railway tunnels, water supply and underground public transport, among others.

WIRTH GmbH | Kölner Strasse 71-73 | 41812 Erkelenz | Germany
P: +49 (0) 2431 83-0 | www.wirth-europe.com | info@wirth-europe.com

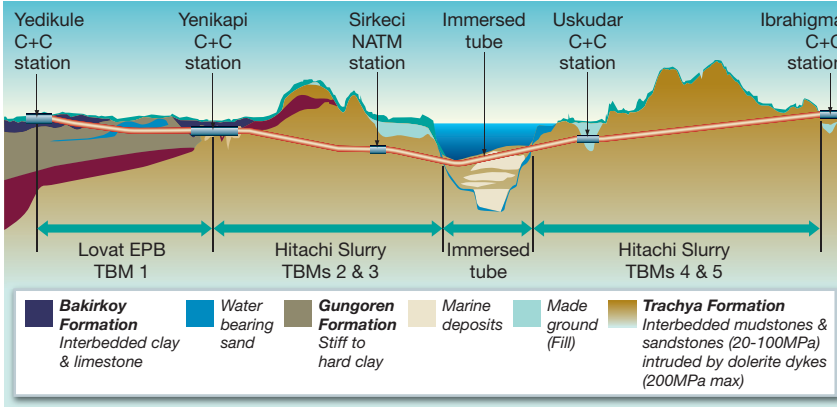


OILFIELD

TUNNELING

MINING

FOUNDATION



Above: Fig 2 - The tunnel alignment with TBM drives and Immersed tube locations



Above: TBM docking element on the immersed tube element



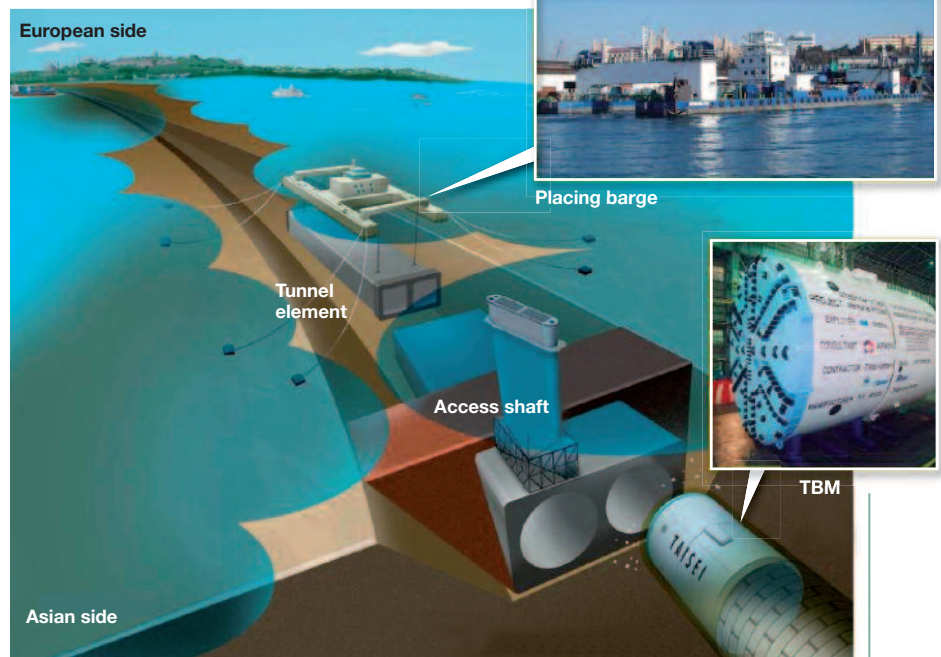
Above: One of the Hitachi Zosen TBMs being used under Istanbul

Pretender investigations were carried out in 2002 to 2003 and comprised 7 marine boreholes with cone penetrometer tests, 26 land boreholes and both land-based and marine geophysics. In 2004, the contractor carried out borehole investigations with maximum spacings of 200m in soft ground, 300m in hard rock and 50m at the stations.

Immersed tube tunnel

The 11 immersed tube concrete tunnel elements are 15.3m wide, 8.75m high, 135m long and weigh 19,000 tonnes and are cast in a fabrication yard 40km from the immersion location. The lower half of the unit is cast in a dry dock and the upper half cast afloat. The gravel foundation is levelled in the trench by a robot grader prior to immersion of the tube element. The units are floated onto underneath a catamaran placing barge, a number of anchors are fixed at the sea bed and the unit lowered into position.

The Employer's Requirements (ERQ) dictate that the immersion operation shall be carried out only when the speed of current through the strait is less than 3 knots. However, the speed varies a lot even in a very short period. Therefore, the ERQ requested that for at least one year continuous current data was collected to develop software to forecast the current velocity at any point for the coming period of immersion. Factors influencing current speed include: atmospheric pressure in the Black Sea and in the Sea of Marmara; wind; rainfall quantity; and salinity. These factors can cause sea level difference of a maximum of 50cm and an average of 25cm. The contractor developed the programme, which



Above: Fig 3 - Schematic of the docking process between TBM and immersed tube

models the currents with an accuracy of 90% and which demonstrates the stratified current in the strait.

For the connection between immersed tube and bored tunnel, the TBM will be driven from rock into a transition zone of low-strength sand-cement, placed by tremie methods, and into circular steel sleeves provided at the ends of the immersed tunnel. The TBM will be sealed into the immersed tunnel and dismantled (figure 3).

Bored tunnel

The finished tunnel diameter is 7.04m. Cross passages will be spaced at 200m. The segmental lining of a six-piece ring plus key will be constructed of concrete grade C50 reinforced with 132kg/m³ of steel, the segments are 300 and 320mm thick, 1500mm wide and each one weighs 4.4 tonnes. There is no fire protection in the lining concrete - a 50mm spray-on cementitious material with fire inhibitors is provided at critical areas.

For the drives between Yedikule and Yenikapi stations, one Lovat EPBM has been designed to cut through the stiff to hard clay

with sand layers. It has a cut diameter of 7.994m, and shield diameter of 7.956m giving a 38mm tail clearance. The overall length is 10m; the maximum thrust is 64,000kN and the maximum drive power from seven motors is 2100kW. Muck disposal is via a continuous screw to an open trough conveyor at a rate of 800 tonnes per hour. Accelerated OPC grout is pumped through the trailing shield and Condat CLBF4/M soil conditioning foam is added to the spoil.

The initial 100m excavation of the Lovat drive was completed in November 2007, but expropriation and archaeology issues are delaying the main drive. The anticipated advance rate is 12m/day, penetration speed of 25mm/minute and a target time per ring installed of two hours. Predicted surface settlements are 20mm for overburden less than 10m deep, 10mm for overburden 10 to 20m deep and less than 5mm for overburden >20m deep. The programme allows 18 months for two 2540m long tunnels, comprising 7 months for each drive with 4 months to re-mobilise for the second.

For the remaining drives, four slurry TBMs

have been manufactured by Hitachi Zosen. The excavation diameters range from 7900 to 7930mm. They are designed to cope with a water pressure of 8bar. The maximum thrust is 75,000kN and the maximum drive power from eight motors is 2000kW. The machines can cope with a curve radius of 300m. The cutter head has 56 rock cutting discs and 108 soil picks. The cutters are made of tungsten carbide in a steel matrix. Accelerated OPC grout is pumped through the segment ports. Bentonite is added to the spoil to improve pumpability in the sands and an organic thickening agent is used to improve the slurry viscosity.

At present, TBMs 2 and 3 are awaiting the completion of archeological excavations at the stations on the European side; TBMs 4 and 5 have completed 50% of the tunnels on the Asian side. Some abrasion and pumping related delays have occurred. The anticipated advance rate is 12m per day: the actual rate is 6 to 14m per day with a record advance of 70m in one week and 15m per day. The target time for an installed ring is 2 hours. The predicted surface settlements are 10mm for overburden less than 10m deep and less than 5mm for overburden more than 20m deep.

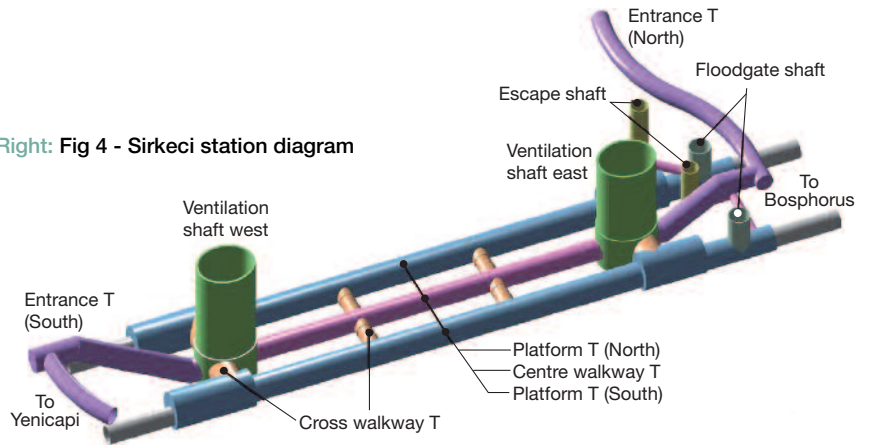
Underground stations

At Uskudar on the Asian side the cut and cover station box is 275m long, 32m wide and 29.5m deep. Soil improvement of soft sand comprised 10m deep by 3m diameter jet grout columns installed by specialist sub-contractor Bauer of Germany. Excavation support was provided by a 1.5m thick diaphragm wall with three 1m diameter reinforced concrete struts. The excavation is 60% complete in a programme stretching



Above: The drive portal on the Asian side of the project

Right: Fig 4 - Sirkeci station diagram



from July 2006 to July 2012.

On the European side the Yenikapi cut and cover station is 250m long, 32m wide and 20m deep. Support is provided by 0.8 or 1m diameter secant piles in a 25m deep wall with 35 tonne tie-back anchors. In a September 2006 to December 2012 programme, excavation is 20% complete.

Sirkeci station on the European Side is 235m long and 60m deep (figure 4). Support comprises 150mm deep steel arches in 300mm thick sprayed concrete and 4 - 6m long rockbolts; 1000mm thick concrete final lining is applied over a waterproofing membrane. The west shaft is 50% complete and the east shaft piling 90% complete. Completion is due in October 2012.

Summary

The benefits of the new railway include the increase in train journeys from 3% to 27% of all passenger journeys and a direct rail, passenger and freight, connection between Asia and Europe. The crossing of the Bosphorus will take 4 minutes and the project will provide an economic benefit of US\$600M per annum. Modern stations and air-conditioned rolling stock will link via seamless interchanges to the planned tram and existing metro systems. Environmental benefits include reducing vehicle emissions, no permanent impacts and no negative visual impacts – the spectacular views over the Bosphorus and Istanbul's historic skyline will be preserved.

T&T

QUESTIONS FROM THE FLOOR

A representative of Tube Lines asked how the tunnels will be ventilated. Mark Gilbey of PB responded that the ventilation exhaust components include over-track exhaust systems for the trackways, under-platform exhaust for the station platforms, tunnel ventilation fans at both ends of each station and jet fans at selected locations.

David Powell of Mott MacDonald asked what specific measures were installed at the interfaces between the immersed tube and bored tunnels to cope with differential settlement and potential leakage. Daniel Horgan responded that the immersed tunnel was designed with two seismic joints comprising water-proofed concrete and 6mm steel plate – these allow a certain level of rotation.

Bob Peters, retired, asked whether in a large earthquake the scheme could be recovered in seven days. He had been involved with work, which had predicted the earthquake along the North Anatolian Fault and the very high horizontal forces responsible for the collapse of an NATM-built tunnel in Bolu. The next major earthquake is likely to be in Istanbul – is the final lining reinforced and what measures have been taken to guard against the effects of earthquakes? Daniel Horgan responded that the tunnels can withstand a

substantial earthquake in which 90% of the buildings in Istanbul would fail. However, an earthquake during construction would cause significant damage. Bob Peters also asked what was the driving force behind the archeological excavations. Daniel Horgan responded that a Heritage Committee had been set up and given supreme powers to preserve archeological artifacts.

Neville Harrison, consultant to Mott MacDonald, asked who pays for the archeological investigations. Daniel Horgan noted that contract BC1 includes a provisional sum to cover this.

Richard Loudon, Travers Symonds, asked what ground improvement was in place for the foundation of the immersed tube elements. Douglas Madsen responded that soil replacement was recommended by the contractor's design.

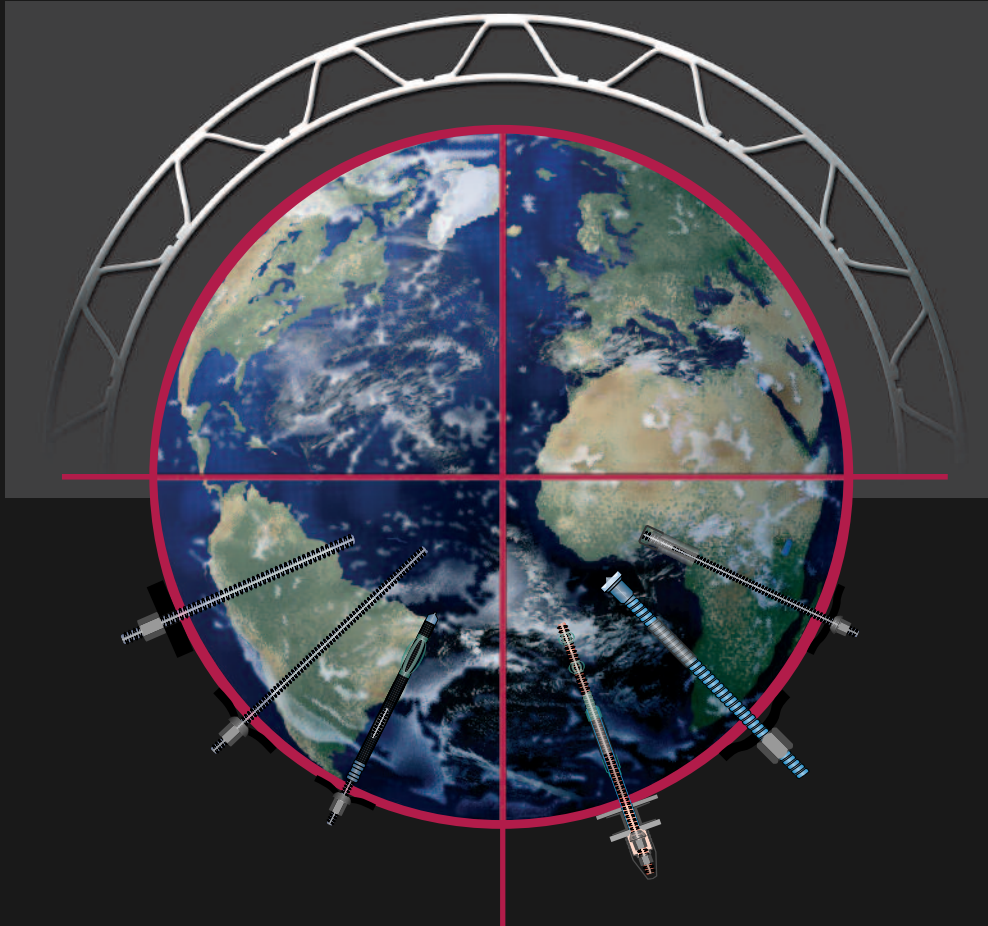
Haydn Davies, London and Continental Railways asked why steel and polypropylene fibres were not used in the tunnel segments and noted that only one structural repair was needed on the CTRL. Douglas Madsen responded that the contractor's design called for bar reinforcement cages and a different type of fire resistance.

Rapporteur: Rory McKimm

FURTHER READING

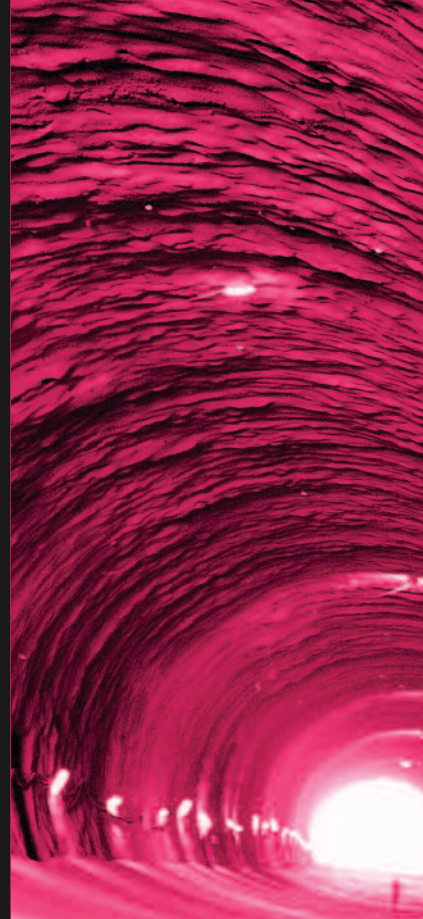
The Marmaray Project. PB Network Issue No. 65. http://www.pbworld.com/news_events/publications/network

GROUND CONTROL SOLUTIONS



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

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



Rock Reinforcement

DYWIDAG THREADBAR® Anchors
 Rebar Rock Bolts and Spiles
 IBO, IBI & DYWI® Drill
 Self-Drilling Bolts and Spiles
 Expandable Friction Bolts
 AT – Power Set Self-Drilling
 Bolts and Spiles
 Mortar-Mixing Pumps

Rock Support

Steel Arches and TH-Beams
 Liner Plates
 Pantex Lattice Girders
 AT – LSC-Elements
 Lining Stress Controllers

AT – Casing System

AT – Pipe Umbrella
 Support System
 AT – Drainage System
 AT – GRP Injection System

DYWIDAG-SYSTEMS INTERNATIONAL



Local Presence – Global Competence TUNNELING SYSTEMS

www.dsi-tunneling.com

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



Pasching
 AUSTRIA



Bristol, VA
 USA



Nottingham
 UNITED KINGDOM



Santiago de Chile
 CHILE



Bennetts Green, NSW
 AUSTRALIA

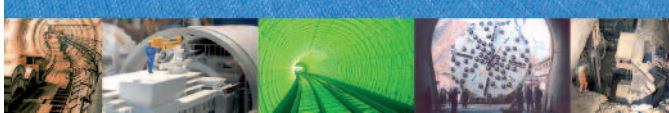


Perfect Connections.



InnoTrans 2008

International Trade Fair
for Transport Technology
Innovative Components · Vehicles · Systems
23 - 26 September, Berlin
www.innotrans.com



Overseas Trade Show Agencies Ltd.
9 Manchester Square - W1U 3PL - London
Telephone: +44 20 7886 3000 x3107 · Fax: +44 20 7886 3101
E-Mail: bente.mckenzie@montex.co.uk · www.otsa.net

 **Messe Berlin**

EXPECT MORE.

DRILL MORE.

ROCKMORE.

Tunnelling- for over 50 years Rockmore has provided innovative drilling solutions for your underground needs with outstanding selection and service.

Look to us for a complete line of:

- Bits
- Couplings
- Rods
- Shank adapters

Manufactured in the USA and Austria



ROCKMORE
INTERNATIONAL
Rock Drilling Tools



Wilsonville, Oregon USA
Tel (503) 682-1001
Fax (503) 682-1002
Email: info@rockmore-intl.com

Judenburg, Austria
Tel ++43 (0) 35 728-6300
Fax ++43 (0) 35 728-4179
Email: austria@rockmore-intl.com

www.rockmore-intl.com

EF Consult Asia can supply the skilled personnel requirements of contractors, consultants, specialist engineering practices and project owners involved in tunneling and other underground construction wherever they are in the world. Project types include metro and railways, highways, hydropower, water services, and utilities. EF Field service has a record of continued success through keeping up to date with and meeting industry needs for tunneling, associated construction, mining, quarrying and mineral processing

We can provide personnel for Hard Rock, EPB and Mix Shield TBM's, backup and related support services

1. TBM Engineer
2. General Foreman
3. TBM Mechanical Foreman
4. PLC Electrician
5. TBM Operator
6. TBM Electrical Foreman
7. Cutter Workshop Foreman
8. Conveyor Foreman
9. Loco Foreman
10. Ring Building supervisor
11. Grouting Supervisor
12. Precast Plant Superintendent



The selected persons are a team and have experience of at least five to seven years (at least of two TBM projects). Please response with Salary bracket (Budget) in EURO, for each category /position the facilities and packages shall be commensurate with the industry standard.

(Malaysian, Indian, British, Austrian, Philippine, nationalities) The immediate availability of the candidate is the main criteria. Other Perks and Benefits shall be as per industry standard

***Interested parties can also write in to strengthen our workforce**

Erich Felfernig Asia Pte Ltd

Your Professional Partner in Tunneling

Tel: +65 6515 1970

Fax: +65 6515 1971

e-mail: info@ef-asia.sg

Website: www.ef-asia.sg

www.d-t.sg



A unique metro accident in Brazil

Right: The Pinheiros station cavern and shaft collapse of 12th January 2007

The sudden collapse of Pinheiros Station and station shaft during construction of the São Paulo Metro Line 4 shocked the industry. Consultant, Nick Barton describes the events

On Friday 12th January 2007, a dramatic metro construction accident occurred in São Paulo, Brazil. Nearly the whole of one of the station caverns of 40m length suddenly collapsed, immediately followed by collapse of nearly half of the adjacent 40m diameter and 35m deep station shaft. Seven people lost their lives in the collapse.

These station and shaft constructions are close to the Pinheiros River, in the SW sector of the city, and are part of the new Line 4



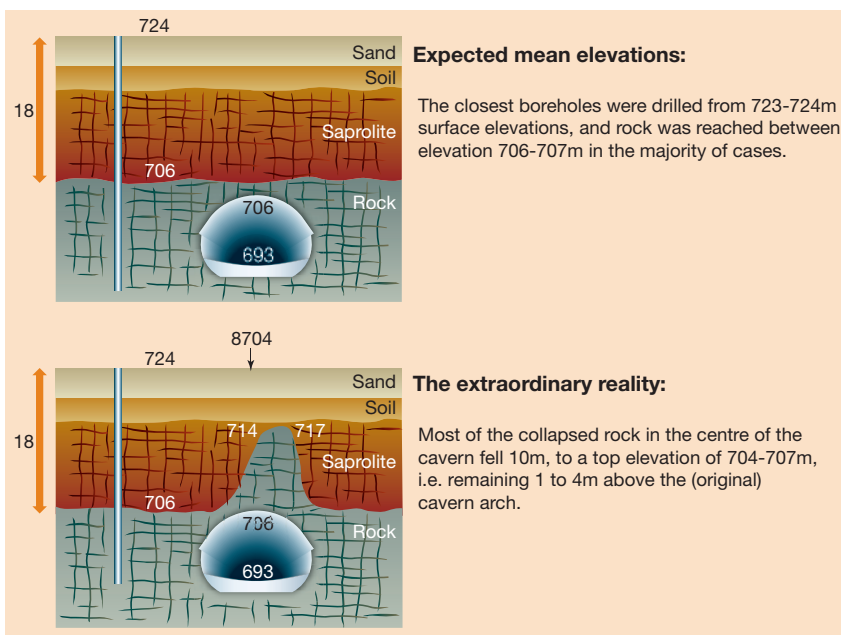
(Yellow Line) of the presently expanding São Paulo Metro. The consortium CVA, Consorcio Via Amarela, composed of most of the major contractors in Brazil, were awarded the detailed design and construction of Line 4 in 2004.

The accident occurred so rapidly that there was no time for warning to be given. It is probable that suction, caused by the rapid fall of a huge undetected ridge of jointed, foliated and often deeply weathered rock weighing some 15,000 to 20,000 tons, causing an air blast in the running tunnel, actually sucked the seven Rua Capri victims to a lower level in the debris than they would have fallen if materials had been more uniform. Five of the victims were in a small bus, others were pedestrians in Rua Capri.

Boreholes for site investigation

Prior to final design and construction of the 18m span station cavern, numerous boreholes had been drilled through the soil, saprolite and weathered Pre-Cambrian gneiss. There were eleven boreholes drilled around the shaft and eastern station cavern. The four boreholes located close to the sides of the cavern, and one almost in the centre of the cavern, had indicated some zones of deeply weathered rock, especially in the biotite gneiss. Foliation was mostly steeply dipping to vertical.

The arch of the Pinheiros station was at a mean elevation of 703m. Borehole 8704 drilled near the centre of the cavern, had correctly indicated a (local) top-of-rock elevation of 706m. This was exactly the same as the mean rock elevation found in the four other closest holes.



Above: Fig 1 - Top) Sketch of the anticipated top-of-rock elevations based on the five nearest boreholes, including one hole near the centre of the cavern. Bottom) Sketch of the extraordinary reality, in over-simplified form



Top quality equipment.



www.grafocom.it



Research, technological development, innovative processes and excellent quality are the objectives of a leading company whose projects, at the service of the world of "concrete", offer performance reliability, cost-effective services and operator safety.

The conjunction of technique, safety and development as well as the collaboration with university centres par excellence, demonstrates the choice made by Cifa to offer all types of equipment with extremely high technical performance levels.

CIFA S.p.A. >> Via Stati Uniti d'America, 26 >> 20030 SENAGO (MI) Italy >> Tel. +39 02 990 131 >> Fax +39 02 998 1157 >> cifa@cifa.com >> www.cifa.com

High-Shear Mixers up to 2500 litres
Grout pumps up to 200 bar
Pressure and flow recording systems
Compact grouting units

Fully automated mixing
and grouting plants
Backfill systems
Packers



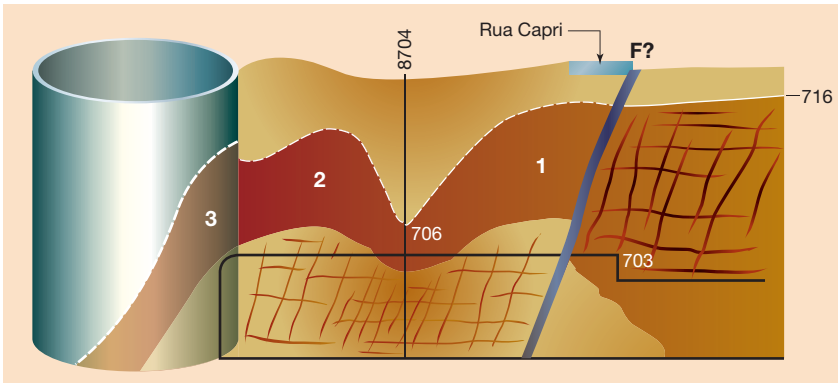
First choice

GROUTING SYSTEMS

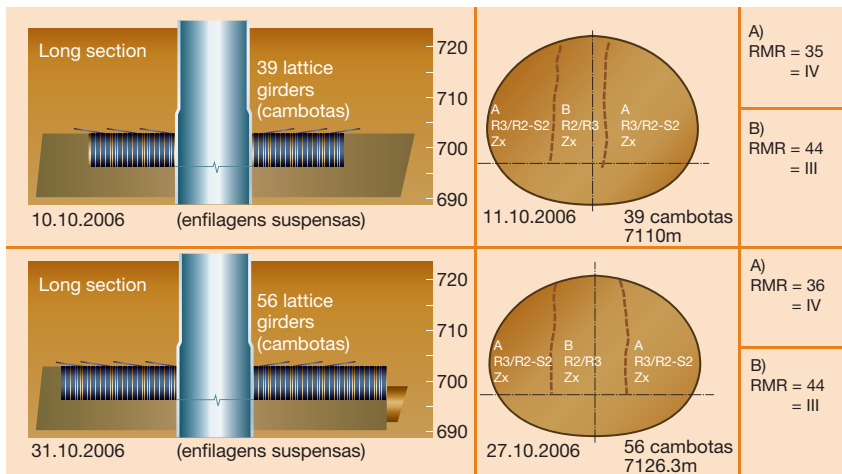
HÄNY

Häny AG • Bergstrasse 103 • P.O. Box • 8706 Meilen/Switzerland
Phone +41 44 925 41 11 • Fax +41 44 923 62 45 • info@haeny.com • www.haeny.com





Above: Fig 2 - The undetected ridges of rock (1, 2) missed due to the location of hole 8704



Above: Fig 3 - Longitudinal sections showing progressing number of lattice girders at two of the mapped cavern faces. The RMR rock class values of the 'core' (B) and the surrounding rock (A) are listed. Pre-injection screens (enfilagens) were suspended after #3 due to improving rock quality and reduced grout take towards the eastern end of the cavern under Rua Capri.

Undetected sub-surface ridge

The tragic contrast between interpretation and reality, following 1-year of excavation through 30m of the collapsed soil, saprolite and jointed and foliated gneiss, is indicated in simplified diagrammatic form in Figure 1.

Two central ridges of less weathered rock with sloping sides provided the 'geometry' for potential failure. However, final collapse is believed to have been triggered by water pressure and clay-softening caused by leakage from a cracked pipe, which crossed a major discontinuity at the rear of the slide.

Rock logging and pre-grouting

During construction of the eastern station cavern, geologists had registered an increasing volume of medium quality Class III rock (RMR = 44-48) in the centre of the cavern in the direction of Rua Capri. The Class III 'core' was surrounded by poorer quality Class IV rock (RMR= 34-36) on either side (figure 3). That this better quality rock 'core' could be a threat to cavern stability was not of course imagined, until with the benefit of hindsight following the collapse, the possibility of differential weathering was considered, since a high ridge of rock was now indicated, in contradiction to earlier borehole evidence. Independent Q-logging of the five closest boreholes subsequently showed a range of Q= 0.1-4, similar to

earlier logging by IPT for São Paulo Metrô, and similar to the contractor's RMR-logging within the cavern.

Station arch primary support

Normally the process of arching, as with a high quality rock mass, results in the need for the designed support to bear just a small fraction of the overlying load of rock. A conservative primary structural support was used to maintain stability as the cavern arch was excavated. The lattice girders had close spacing (0.85m c/c) and were embedded in a minimum thickness of 35cm of steel-fibre-reinforced sprayed concrete.

Because of the weaker rock at the sides of the cavern, conservative assumptions were made for the foundation strength and stiffness of the rock beneath the footings of the lattice girders supporting the top heading. The so-called 'elephant feet' supporting the structural arch, were placed in large excavated recesses in the rock, at either side of the cavern.

CVA excavated with small drill-and-blast advances and applied the successive structural support elements up to the face, followed by shotcreting. An earlier Basic Design lattice girder spacing of 1.25m c/c was rejected because of the loads resulting from the assumed inadequate rock cover, as the desirable arching in the rock above the



Top: A view of the heavy primary support in the top heading of the eastern station cavern. Lattice girders were at 0.85m c/c spacing, embedded in at least 35cm thickness of steel fibre-reinforced shotcrete

Above: View of the cavern (and running tunnel) some days prior to collapse

cavern was expected to be much reduced.

A lighter, cheaper primary support alternative for the cavern, consisting of rock bolt reinforcement of the rock arch, and significantly less sprayed concrete thickness was rejected, since the five closest boreholes had indicated a mean top-of-rock elevation of 706m, only 3m above the cavern arch roof. This was considered insufficient for conventional support with rock bolts, since this rock was also deeply weathered in various locations, with UCS expected to be 5 to 10MPa, sometimes even less than this.

Final support of this large multiple-component station structure was to have consisted of steel-reinforced concrete. However this stage of construction had not been reached at the time of collapse, either in the eastern or western station caverns, or in the central station shaft. A first 4m high bench to elevation 693m was completed, prior to accelerated deformation in the last three days before the collapse. This abruptly followed several months of gently increasing, then stable maxima along the cavern, ranging from 14 to 24mm.

Likely collapse mechanisms

During most of 2007 and in the first 3 months of 2008, the fallen rock sketched in Figure 2 was carefully excavated, under the supervision of a government institute IPT,



Above: Assessing the damage following the collapse, notice the bent lattice girders

working on behalf of the Police. This post-collapse excavation was performed from the base of an increasingly deep open excavation supported eventually by hundreds of tie-backs. It will eventually be completed as a cut-and-cover station platform construction.

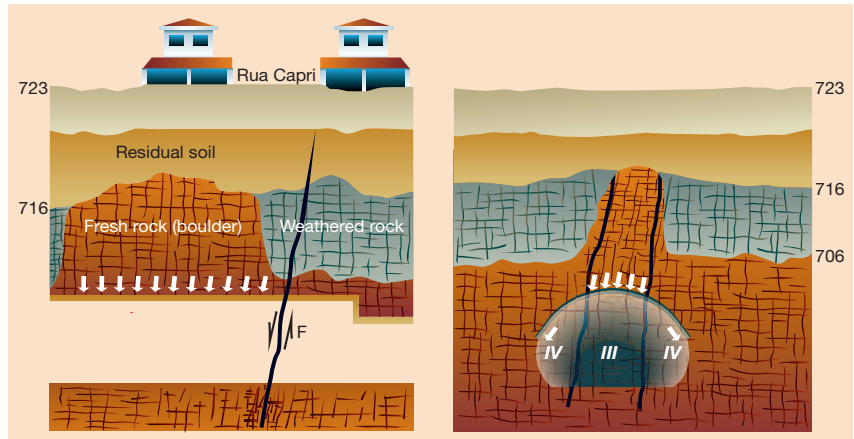
Differential weathering along the sides of the 10 to 13m high ridge of rock was identified during this post-collapse excavation. At some distance above the cavern arch, this unidentified wedge-shaped ridge had developed into a threat to stability, due to its adversely sloping clay or soil-filled boundaries which hindered arching, and instead stood ready to supply a huge load onto the lattice girders and steel-fibre reinforced shotcrete support.



Above: Evidence for 'elephant-footing' failure

Right (top): FRACOD modelling of rock fracturing caused by over-stressing of the lattice girders in the cavern arch, caused by the unknown elevated ridge of rock

Right (bottom): Final stage of collapse in a UDEC model of the lattice-girder and S(fr) supported cavern, following softening of plastic hinges in the arch. Footing failures with local jointing were also modelled



Above: Fig 4 - Conceptual model that was developed as a possible explanation of the final stage of differential weathering, leaving a ridge (and wedge) of rock that threatened stability as it prevented efficient arching above the cavern due to clay along its sides

Figure 4 shows conceptual drawings of what is believed to have caused the failure of the cavern: a jointed and variously weathered 'ridge-of-rock' structure, that must have had its origin in differential weathering between what, at cavern level had been class III rock (the 'core') surrounded by the poorer class IV rock which presumably weathered more easily as the surface was approached.

Mechanism seen in the support

The collapsed parts of the cavern's structural support were reached by February 2008, at elevations of 693 to 695m, immediately above the original cavern floor level of 693m. The cavern had been excavated to a height of 10m when the collapse occurred. A final bench had remained to be excavated below this level, in mostly sound rock.

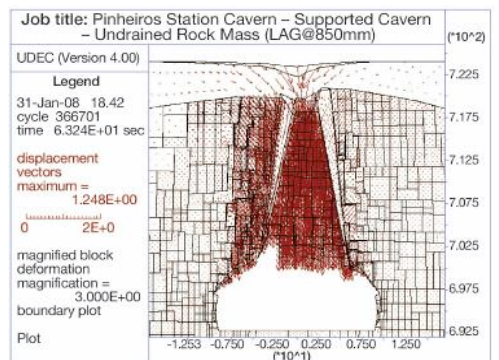
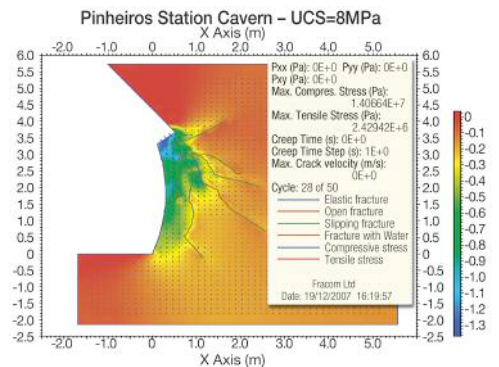
Evidence for extreme over-loading of the structural support, causing its immediate collapse was eventually exposed near the

base of the excavations, which continued through March 2008, more than 14 months after the collapse. In part of the cavern there was evidence of footing failure, meaning fracturing of the rock beneath the 'elephant-footings', followed by folding and inwards displacement of wall shotcrete and mesh.

There was however, more extensive evidence of extraordinary 'punch-loading' of the heavy arch support, with multiply folded layers of structural support, and even of lattice girder steel failed in tension. This is evidence of extremely unusual, and probably high-velocity loading levels.

Computer modelling

The likely mechanisms of failure of the support could be partially demonstrated in post-collapse discontinuum (jointed rock mass) modelling, and in stress fracture modelling of the over-loaded 'elephant footings'. These models were performed by Dr. Baotang Shen (FRACOD) and by Dr.





Above: Shear deformation on this major discontinuity when the cavern approached and passed below, may already have fractured this 700mm pipe

Stavros Bandis (UDEC). The FRACOD model showed cracked foundations beneath the 'elephant-footings', when realistic levels of rock strength, fracture toughness, and exceptional rock ridge loadings of up to 20,000 tons were modelled. There was no cracking in any of the three cases (UCS = 5, 10 or 15MPa) when load levels were low, as reasonably expected in the design. The UDEC model showed a final stage of cavern collapse in progress, as the wedge-shaped-ridge of rock begins to fall. This code was not used in design studies due to the limits of investigation by small-diameter drillcore.

Adverse features

A collapse of this magnitude, occurring with a speed sufficient to cause an air-blast that blew over a distant fleeing tunnel worker, obviously required other adverse features for it to occur at this location. There were by chance three additional adverse features exactly beneath Rua Capri. Taken alone these additional factors would not have been a threat to stability, but in unexpected combination they caused one of the largest urban civil engineering tunnelling accidents on record. The triggering mechanism for this loading to be released proved to be totally unexpected.

Geological faults or major discontinuities crossing tunnels or caverns occur so frequently that the tunnelling industry developed standard support measures long ago. In the case of Pinheiros, a smooth major discontinuity crossed the cavern at a steep and nearly perpendicular angle. This is most favourable in normal circumstances. At cavern level 20m below, this feature did not distinguish itself from the smooth, planar rock joint (fracture) set that consistently crossed the cavern at the same steeply-dipping angle. The standard heavy support was continued to the eastern end of the cavern. In this end of the cavern, beyond the major discontinuity, no collapse occurred.

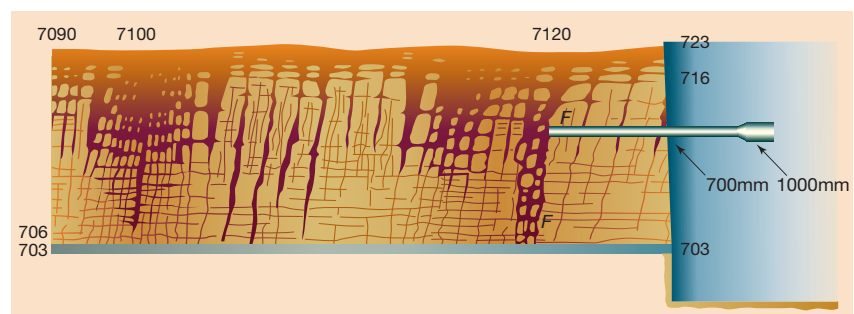
The unpredictable event that probably triggered the massive instantaneous failure along the multiple adverse rock structures lying undetected above the cavern is

believed to be the cracking of a 30 years-old 700mm diameter sewage and storm water pipe that crossed the same discontinuity exactly beneath Rua Capri. Compounding the situation was the fact that this potential artificial water supply was located immediately following a change of cross section of the pipe, from 1000mm to 700mm. This represents a 50% reduction in flow area, which probably caused an elevated water pressure and unwanted water supply in just the wrong locations.

Naturally there had never been a cavern under this discontinuity marking the eastern boundary of the collapse. It is surmised that there may have been some down-dip sliding deformation as a result of the approaching and passing cavern arch. This can never be prevented, and is of small millimetre-scale magnitude, but it may have allowed the water from the cracked pipe to flow more easily, transmitting pressure further into the unknown, adverse rock structures.

The artificial water supply, seen flowing from the broken pipe in a video film taken immediately after the collapse, would have helped to soften clay along the boundary discontinuity (marked FF in figure 5), and also have had the potential to soften and lubricate the weathered boundaries of local parts of the adverse wedge-shaped ridge of rock running undetected above much of the cavern arch. Reduced effective stress resulting from increased pore pressure is another possibility for accelerating the onset of failure.

The final block release surface at the



Above: Fig 5 - The fractured pipe, with the change of cross-section and possible raised water pressure occurring in just the wrong location. Rua Capri pavement is at ch 7120m

other end of the largest rock ridge may have been the deeply weathered boundary between the two 'halves' of the ridge, in the approximate location of borehole 8704, at an original chainage of 7100m. Alternatively there could have been 'down-stepping' across the smooth steeply dipping cross-joints that crossed the cavern at numerous locations. The second smaller rock ridge effectively had the shaft wall as its western release surface.

A final unexpected factor that may have compounded the scale of collapse at Pinheiros, was the distant 75° to 80° dipping rear discontinuity (FF) under the eastern pavement of Rua Capri. Although nearly 40m from the shaft, the down-dip component of sliding during the 10m collapse, may have pushed both the falling ridges of rock some meters towards the side of the shaft, thereby further guaranteeing the shaft's partial failure.

Inevitably, when an adjacent circular shaft that relies on circular and radial loading, suddenly loses a large portion of its circumference, due to collapse of the station cavern, there is insufficient stiffness in the primary lining phase to resist the uneven and dynamic load. Failure of part of the shaft is then inevitable.

Conclusions

The 2007 accident at Pinheiros focussed engineers and planners attention on risk, especially in the case of sub-urban tunnelling in São Paulo. Regrettably the high cost and physical impossibility of performing necessary but quite unreasonable levels of sub-urban site investigation could prevent the execution of many shallow city metro projects. This would be due to the socially and commercially unacceptable degrees of disturbance beneath too many roads and buildings. Deeper construction from the underground, as practised of necessity in many cities lacking suitable geology, could be a future solution, as rock conditions for tunnelling are fundamentally more favourable at depth, whereas the 'near-surface' is more unpredictable due to deep weathering in such tropical regions.

T&T

GEO FLUID

DRILLING & FOUNDATIONS

2008

1-4 October
Piacenza - Italy

17th International exhibition & conference
of technology and equipment for
Prospecting, Extracting and Conveying
Underground Fluids



Tunnelling
Machines,
Equipment
and
Instrumentation



Drilling Rigs and
Equipment for
Underground
Investigations,
Special
Foundations and
Trenchless
Technologies



Instrumentation
and Equipment for
Environmental
Analysis,
Monitoring and
Land Reclamation



www.geofluid.it



Products

Environmental upgrades for fleet

In a project to upgrade its underground equipment with new diesel engines to meet the latest requirements in Europe (Stage IIIA) and North America (Tier 3), Atlas Copco has redesigned and modified many of its face drilling and production drilling rigs as well as bolting and scaling rigs – affecting changes that are clearly positive for owners and operators.

Apart from the improved environmental impact provided by the new, lower emission engines, the design changes on the major part of the rigs have resulted in better hydraulic and automatic systems, increased safety and ergonomics, easier servicing and better reliability.

Project Manager Peter Öberg, who is managing the project at Atlas Copco's manufacturing facility in Örebro, Sweden, says: "In

making design changes to accommodate the new, lower emission engines we have been able to use the opportunity to redesign and modify a great many details that give improvements and benefit to the users."

"We have been able to increase the overall strength on several models which means that the rigs can carry heavier optional equipment. Due to new component layout and placement, serviceability and maintainability have been improved."

Most of the new installations and upgrades have already been incorporated into the company's assembly system.

Atlas Copco

Tel: +46 (0)19 670 71 19

Email:

mikael.ramstrom@se.atlascopco.com

Web: www.atlascopco.com



Improved installation

Flexco, the belt conveyor specialist, has announced the release of its improved Aluminum MSRT Installation Tool complementing the Flexco® SR[®] Fastening System with a focus on providing a lightweight, portable application tool. The Aluminum MSRT Multiple Rivet Driving Tool has been designed to assist splice installers in harsh working environments where heavy splicing equipment has to be moved on a regular basis.

The tool's new scalloped design of the riser plate allows for fast, accurate alignment of fastener strips on the anvil plate. The riser plate positions the belt for easier feed into the fastener strips.

The robust design of the clamp bar with Acme threading provides maximum holding capabilities, especially on thick, high tension belts where a safe strong hold is required. The clamp bar and riser



plate have been designed with serrated grips for more secure clamping and operator efficiency.

Using the Rapid Loader[®] Collated Rivet Strips to load 20 rivets at one time will ensure reduced installation time and increased operator efficiency. The entire guide block can be loaded with one strip of collated rivets.

Flexco

Tel: +1 (630) 971 0150

Email: rsouffrant@flexco.com

Web: www.flexco.com

Want to know what lies ahead?



We know for certain!

The more you know about the rock, the better you can drill it. Make the control system of your Atlas Copco Boomer drilling rig still more efficient. Our upgraded Tunnel Manager PC software will reveal the rock's secrets – and smooth the way ahead! Available in three versions, Tunnel Manager gathers, stores and analyses key measuring data throughout the drilling process. The most advanced version features MWD (Measure While Drilling) software, for speedy rock quality analysis – offering the unique ability to adjust for optimal productivity throughout the drilling process.

Committed to your superior productivity.

Atlas Copco Underground Rock Excavation
www.atlascopco.com

Atlas Copco



The leader in Separation Plant Technology from small to large scale plant worldwide

Schauenburg MAB GmbH
Weseler Straße 35
45478 Mülheim a.d. Ruhr / Germany
website: www.schauenburg-mab.com
e-mail: hwm@hwm-engineering.de
phone: +49 (0) 208-9991-0
fax: +49 (0) 208-592-409



SCHAUENBURG MAB

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

Web-based Tunnel Monitoring and Data Visualization.

Data Visualization Software

Datalogger System

Concrete Stress Cells (NATM Style)

For more information, visit: www.geokon.com/dm

GEOKON The World Leader in
Vibrating Wire Technology

1-603-448-1562
info@geokon.com
www.geokon.com

The making of the Mixshield – Part 1

In the first of a two-part series, Werner Burger, head of design and engineering, and Gerhard Wehrmeyer, director of traffic tunnelling, for Herrenknecht AG, examine the development of the modern Mixshield

Since its initial introduction, in 1985, the Mixshield TBM has taken on an essential role within the world of mechanical tunnel excavation. With its ability to operate as a classic slurry-shield, or change to Open or Earth Pressure Balance (EPB) mode mid-drive, the Mixshield offers a unique concept for dealing with mixed ground excavation conditions.

In order to appreciate how these machines have evolved, this article looks at the history and development of Mixshield technology over recent decades and the impact this has had on the underground construction industry.

Development of technology

The first European attempts to develop a bentonite shield began in England in the early 1960s, leading to the excavation of a short experimental tunnel in London, in 1971. German contractor Wayss & Freytag took these initial ideas and built upon them, incorporating an air bubble principle to control and regulate face support pressure.

These early machines were mainly used in gravel and sand under lower water pressure, such as the Wilhelmsburg CSO tunnel, in Germany, which was completed in 1974. The shields were equipped with a centre shaft drive and light spoke-type cutterheads with square drag tools, reflecting their limited range of application at that stage.

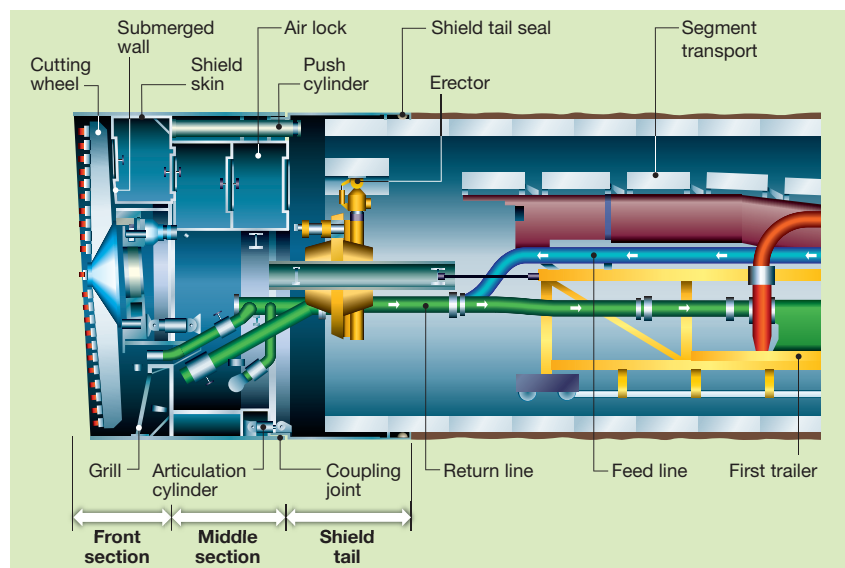
With a view to finding an alternative to conventional compressed air excavations, which were common at the time, Wayss & Freytag concentrated on the design of face support systems and the development of a tail shield seal that would stand up to the rough conditions of mechanical excavation.

In parallel with these developments, the evolution of water-resistant single-shell concrete segmental linings occurred.

Early Mixshield concepts focused both on the development of a shield that would provide a slurry supported tunnel face and also an open shield that could enable a change of operational model^[1]. That is why,

even today, the term “Mixshield” is still used for “slurry only” machines as well as for convertible shields. In all cases, however, the use of a submerged wall/pressure bulkhead combination, to create an air bubble for face pressure control, has remained an essential design feature for this type of machine.

Right & below: Fig 1 - The HERA Mixshield



The Mixshield is ultimately distinguished by the following features:

- A modular design that allows adaption to different modes of operation (slurry, open, and EPB) for different projects, or a fully-equipped machine for changes mid-drive
- Centre-free cutterhead drive with three-axis roller bearing for a centrally arranged muck transportation system (screw or belt)
- Centre-free cutterhead drive to accommodate various media (water, bentonite, hydraulics, electrics, etc) into the cutterhead and excavation chamber via a rotary joint
- Integration of a cutterhead support system with axial and radial articulation by means of a spherical bearing

The first application of a true Mixshield machine was at the HERA tunnel, in Hamburg, in 1985. This 6.2km-long project accomplished advance rates of up to 20m/day. The developments introduced proved successful, following a few adaptations during tunnelling, and confirmed the suitability of the new design.

Like other early Mixshields, the HERA machine had a cutterhead that tilted forward at 3°. The idea was that a slightly inclined face would help with face stability. However, with growing experience and confidence in the principle of a bentonite-supported face, this mechanically cumbersome configuration eventually disappeared in favour of vertically mounted cutterheads.

Table 1: Developments in Mixshield technology

Year	Project	Development
1985	S-12 HERA	<ul style="list-style-type: none"> Mixshield: Centre free cutterhead drive Passive shield articulation joint Grouting through tail shield with external grout lines
1987	S-21 Lille	<ul style="list-style-type: none"> Main bearing as three axis roller bearing Centre flushing Single lip tail seal type S1 Double erector with semi-automatic mechanical gripping
1988	S-41 Nuremberg	<ul style="list-style-type: none"> Fully-articulated cutterhead with spherical bearing Cutterhead with mixed face tool arrangement including disc cutters Grouting through tail shield
1988	S-47 Duisburg TA 6	<ul style="list-style-type: none"> Jaw type rock crusher in invert (initially without grill in front of suction pipe - added later)
1989	S-50 Grauholz	<ul style="list-style-type: none"> Mixshield as convertible shield: Changing operation mode slurry – open Large diameter > 11m Operating pressure 4bar Cutterhead flushing Fixed centre plate cutterhead drive with inner seal system Compensation pipes excavation chamber – pressure chamber Vacuum erector Invert fill within backup area Data recording
1989	S-52 Mülheim BA 8	<ul style="list-style-type: none"> Hard rock cutterhead with disc cutters in pressurised slurry Articulated suction pipe Slurry supply in front of submerged wall Hard rock TBM: Thrust cylinder skew controlled Hydraulic wing type stabilisers 17" backloading cutters only Bolt-on bucket lips
1991	S-67 Strasbourg	<ul style="list-style-type: none"> Closed cutterhead with back loading scrapers Hydraulically extendable gauge cutter Agitator wheels in front of suction pipe Re-circulation system to increase slurry flow within excavation chamber Initial application of wire brush tail seals on a Mixshield Segment supply in invert area Automatic "weekend control" for slurry suspension supply
1992	S-68 Essen Lot 34	<ul style="list-style-type: none"> Active centre cutter with independent slurry feed and suction lines Extendable face plates Submerged wall front gate
1992	S-71 Köln Los M1	<ul style="list-style-type: none"> Floating thrust cylinders with hydraulic clamping system
1994	S-85 Duisburg TA 7/8	<ul style="list-style-type: none"> Conversion of operating modes slurry – EPB via exchange of invert shield segment in shaft Drill tubes through skin for pre-excavation grouting and probing Open cutterhead centre with independent slurry feed and suction line
1996	S-103 Sydney	<ul style="list-style-type: none"> Rotary crusher / sizer Unidirectional mixed face cutterhead
1997	S-108 4 Elbröhre	<ul style="list-style-type: none"> Accessible cutterhead for atmospheric cutter tool change Face pressure 5.5 bar World largest shield diameter: 14.2m Preparation for diving activities Hyperbaric rescue shuttle Support pressure control to match tidal changes
1998	S-127 Socatop	<ul style="list-style-type: none"> Conversion of operating modes slurry – EPB in tunnel
1999	S-137 Westerschelde	<ul style="list-style-type: none"> Initial use of saturation diving up to 7.5 bar Long-distance tunnelling with permanent face pressure >4 bar Initial use of hyperbaric transfer shuttle and living chamber
1999	S-150 Sophia	<ul style="list-style-type: none"> Continuous mining in soft ground with positive face support
2000	S-152 Wesertunnel	<ul style="list-style-type: none"> Closed invert segment
2005	S-246 Hallandsås	<ul style="list-style-type: none"> 13 bar max operational pressure Convertible TBM with fines handling flushing circuit in open mode
2006	S-317/318 Chongming	<ul style="list-style-type: none"> World's largest shield diameter: 15.43m Improved cutterhead access for atmospheric cutter tool change

Another obvious design feature on early machines was the wide open, light cutting wheel design and a large submerged wall opening. It was thought that these were essential requirements to ensure the best possible bentonite circulation and therefore stability of the face. As with the inclined face, however, it became obvious these were not mandatory requirements and that cutterhead designs more appropriate to mixed face conditions could be employed without negative effects on face stability or settlement. The difference in layout between slurry shields and EPB cutterheads therefore started to disappear^[2]. Today's cutterhead designs are driven by a much wider range of factors – including wear protection, muck flow, tool arrangement and tool access.

In the late 1980s, the potential of Mixshield machines became obvious to the tunnelling community. For the next 15 years, projects and orders were heavily influenced by the market enthusiastically embracing the concept. The development of other soft ground technology, such as compressed air shields and the membrane shield, were all but abandoned in favour of the Mixshield; which had already enabled the completion of projects previously considered impossible.

From a technical point of view, the step-by-step development of the Mixshield (Table 1) reads like a technical requirement catalogue for today's slurry shields. The only difference being that the initial introduction of any new feature on a given project required a huge amount of dedication and commitment from all parties throughout the learning curve.

Early milestones included the application of a Mixshield, used as a slurry machine, in Duisburg, which adopted a jaw crusher for boulders up to 500mm; the use of a hard rock cutterhead in Mülheim; convertible operation modes (closed mode with slurry circuit – open mode with centre belt conveyor discharge system) for the Grauholz tunnel; and Mixshield operation in Strasbourg with slurry support and closed cutterhead in coarse sand and gravel.

Additional progress was made in the mid-1990s with projects such as the fourth Elbe tunnel and the Westerschelde crossing. Since then, advances to larger diameters, higher water pressures and shallower cover have presented a whole new dimension of challenges. Many engineering questions, such as lowering the bentonite level for face access, had to be revisited and new innovative solutions such as accessible cutterheads for cutter tool changes under atmospheric conditions were created.

As well as direct improvements to Mixshield technology, several more general TBM developments have also contributed to the advancement of Mixshields, including:

- Articulated cutterheads to allow

overcutting and full control of cutterhead and main bearing loads

- Floating thrust cylinder systems to address increased segment length and difficult tunnel alignments
- Mixed and variable face cutterhead and backloading tool designs
- High-pressure mainbearing, articulation and tailseal concepts
- Vacuum systems for segment erection
- Advanced systems for data recording and processing or process automation

Many of these more general developments have to be viewed in combination with related advancements, e.g. segment design and manufacturing, soil conditioning, sealant materials, alignment control and survey systems, IT systems and data transfer.

In addition to the conventional use of Mixshields for face support in soft ground, the growing use of closed mode operation in rock tunnels has also been seen in recent years. In water bearing rock with the potential for high water inflows and/or pressure, the control of water inflow through the cutterhead is essential for operational reasons (segment backfill grouting, muck discharge) and, in many cases, even more so for environmental reasons.

The traditional approach to such ground conditions is pre-excitation grouting from within the shield ahead of the tunnel face. Depending on rock conditions, pre-grouting activities can be time-consuming and do not always guarantee success, especially against flowing water. To overcome these problems, a closeable single shield rock machine was developed that would allow pre-excitation grouting using preventer systems against static water pressure. The next logical step was to install an additional slurry circuit muck transport system to deal with worst-case scenarios in closed mode.

Operational modes for such hard rock Mixshields include: a) Open mode with dry primary muck discharge system (e.g. conveyor); b) Open mode with (cyclic) pre-excitation grouting; c) Open mode with (cyclic) pre-excitation grouting in closed static conditions; d) Closed mode with hydraulic muck discharge system under reduced face pressure; e) Closed mode under full-face pressure with potential for positive face support.

Closed mode, high-pressure operation in hard rock provides the most adverse conditions of operation for all components of the machine, but having options d) and e) available is a significant advantage in terms of mitigating potential risk.

The machines for the SMART project in Kuala Lumpur, in 2004, produced the second series of large Mixshield machines, this time partially in medium soft rock conditions.

The spotlight regarding large Mixshield

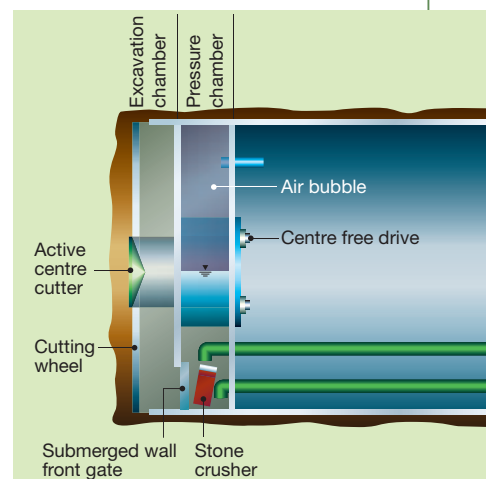


Fig 2: Mixshield concept

machines is now currently focused on the world's largest Mixshield machine, for the Chongming project, in Shanghai.

Face support

As a classic Hydro Shield, the Mixshield applies the necessary face support pressure via a pressure-controlled air bubble in the pressure chamber. A characteristic design feature of the Mixshield is the submerged wall, separating the pressurised front section of the shield into two areas. The area between the submerged wall and the pressure wall is called the "pressure chamber" (figure 2). The area in front of the submerged wall is defined as the "excavation chamber". The required pressure exchange between excavation chamber and pressure chamber occurs via an opening in the bottom of the submerged wall.

Additional compensating pipes that connect the invert area of the pressure chamber with the excavation chamber ensure pressure exchange, even if there is a blockage of the submerged wall opening.

The air bubble is maintained by a self-regulating air pressure control system (with a back-up available if necessary). When under water, where groundwater pressure is influenced by tidal activity, water levels and pore water pressure readings are taken into consideration as additional parameters in the pressure control. For large diameters, the slurry density and level in the pressure chamber may also be used as input parameters. The required face support pressure settings must be determined by calculations for each individual section of the tunnel alignment before the excavation.

Cutterhead access & tool changes

Integral to the general Mixshield concept is the ability to lower the slurry level in the excavation chamber for cutterhead or face access, either remotely from the atmospheric



Marti Technics' belt conveyors for sinuous and sloped environments

Tunnel alignments are not always straight or without gradient. There can be sharp curves and/or upward and downward slopes, both inside and outside the tunnel. Marti Technics' belt conveyors are suitable to cope with such conditions. In case of narrow curve radiuses, it is imperative to use intermediate drives (boosters) to reduce the pulling stress on the belt at the entrance of the curve and guide the belt without reducing the filling capacity. The longer the belt, the worse the stress that the belt has to undergo. The belt tail is fastened to the TBM back-up while the head is fastened to the tunnel portal.

For Line 4 of the São Paulo metro, Marti Technics' first muck conveyance contract outside of Europe, the 7,860 m conveyor belt designed by Marti's engineers includes a head drive at the tunnel portal and three intermediate drives (boosters). The system has the capacity to transport 800 tonnes/hour. It fits perfectly in the tunnel alignment, which has more than 20 horizontal curves along with upward and downward slopes. The total installed power equals 890 kW.

- 1 18 million people live in São Paulo
Photograph: Marcos Hirakawa/Sp Turis
- 2 Inclined conveyor belt on São Paulo's metro line 4

Marti Technics Ltd. Lochackerweg 2 CH-3302 Moosseedorf
Tel. +41 31 858 33 88 Fax +41 31 858 33 89 info@martitechnik.ch www.martitechnik.ch

SIREG DURGLASS® Glass fiber bars, stirrups and rings for temporary reinforcement - Soft Eye Technique. Diaphragm walls, piles, circular beams and anchors can be easily cut by tunnelling machines.



Reference Projects:

- Hong Kong
- Turin
- Paris
- Singapore
- Barcelona
- Brescia
- Istanbul
- Jenbach
- Bratislava
- Malmoe



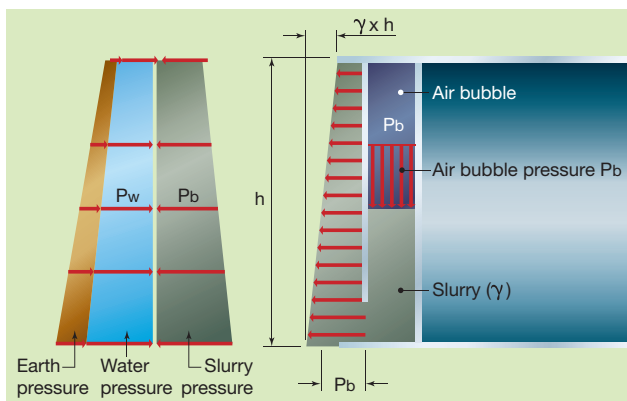


Fig 3: Mixshield face support principle

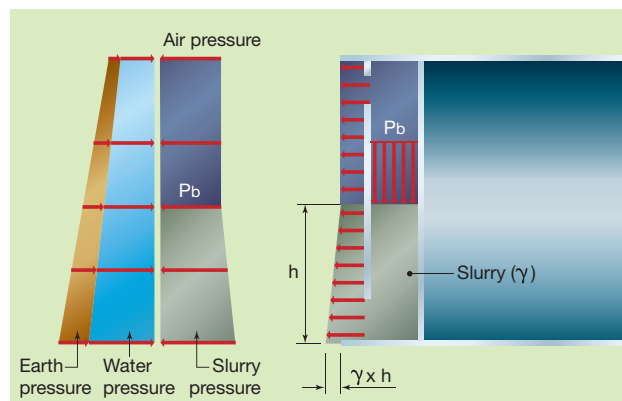


Fig 4: Reduced front level for face access

area behind the pressure bulkhead or from inside the pressure chamber (figure 4). In locations with shallow cover and high water pressure, the level of slurry can only be lowered by a third of the diameter for access to the excavation chamber, in order to maintain sufficient safety against the risk of a blow out. In such cases, the required balance between excavation chamber and pressure chamber has to be controlled from the atmospheric area behind the pressure wall.

The use of a submerged wall gate enables the isolation of the pressure chamber from the excavation chamber. By closing the gate, maintenance work in the pressure chamber can be carried out under reduced pressure or even free air conditions. In this scenario, pressure regulation of the excavation chamber is carried out via a remote pressurised bentonite tank air bubble, usually mounted on the back-up gantries.

A new development for areas of sticky soil with a high clogging risk is the separation of the suction area from the rest of the pressure chamber. This was successfully implemented in the Mixshield used for the Weser tunnel, in northern Germany. Here, the invert area was isolated from the rest of the pressure chamber. Separate connection lines (or "compensation pipes") provided the necessary pressure exchange to the excavation chamber for face support.

With this system, a large percentage of the total flow volume can be circulated through the excavation chamber reducing the slurry density in specific areas and making it more constant. This results in less muck accumulation/clogging, as well as less secondary wear and more even operational conditions for the slurry circuit and treatment plant. The isolated suction area created still accommodates the rock crusher and submerged wall gate.

Maintenance and service operations within working pressures of over 3.6 bar – and therefore outside of the normal framework of compressed air regulations – were successfully performed under special permits on the fourth Elbe tunnel and Weser

tunnel at air pressures of up to 4.5 bar.

Professional divers can be employed for underwater operations or pressure levels beyond 3.6 bar for access into the suspension filled excavation chamber and/or for work to be performed in the invert area of the pressure chamber. Requirements for diving operations need to be established at an early stage of the project and have to be addressed in the design and installation of the TBM. Different applications also have to be defined. For example:

Short-term, submerged dives to explore the tunnel face or to inspect cutter tools: Divers enter the bentonite suspension from the air bubble in the pressure chamber. Submerged wall doors are used to access the excavation chamber. These are located below the suspension level in the pressure chamber. This procedure was successfully implemented at the fourth Elbe River tunnel.

Long-term, for major maintenance and repair work and/or pressures beyond 4.2 bar: Special dive techniques, such as those used in the offshore industry are used (involving mixed gas or saturation diving). In the case of saturation diving, dive crews remain under pressurised conditions for extended periods. The divers are transferred from an above ground "living chamber" to the TBM via a mobile shuttle lock. Depending on their tasks and the pressure levels at which they are operating, the divers can work for several hours before returning to their "living chamber".

Whenever possible, maintenance work in

the pressurised area is done in a dry compressed air environment using masks for the breathing gas mixture. The entire process, including breathing gas mixtures, atmosphere, durations, or individual pressure levels, has to be precisely planned and supervised by experienced specialists. Saturation diving for tunnelling operations was used for the first time on a large scale at the Westershelde project, in the Netherlands.

Crushing rocks and boulders

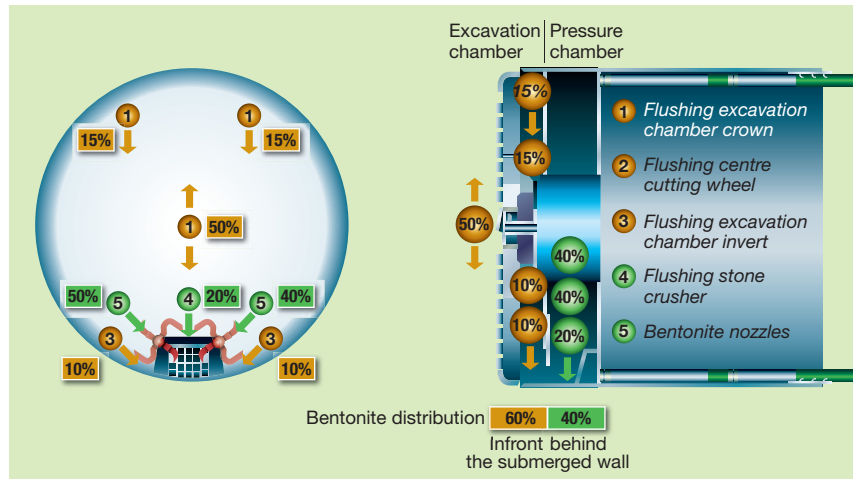
In principle, there are two ways to handle rocks and boulders. Firstly, if the matrix of the tunnel face is strong enough, disc cutters excavate rocks and boulders. In most cases, this excavation mechanism can be used successfully down to boulder sizes of 400mm to 600mm. The remaining rock entering the excavation chamber is then crushed into smaller particles by a rock crusher located in the invert of the machine. The maximum allowable grain size after crushing is dictated by the design of the slurry circuit, especially the size of discharge pipe, pump type and slurry flow speed.

As a rule of thumb the practical maximum grain size can be considered to be about 30-40% of the discharge pipe diameter. The typical arrangement in the suction area for conditions with boulders and cobbles is the installation of a grill for grain size limitation in front of the suction pipe and a hydraulic jaw crusher in front of the grill. Different size jaw crusher capacities are used in different machine diameters:



Jaw crusher (left) and rotary sizer with agitators (right)





Above: Fig 7 - Example of suspension supply to excavation and pressure chamber

Left: 17" monobloc cutter, on the ESCSO Project in Portland, USA

- 4m-6.5m: max boulder size 500mm
- 6m-10m: max boulder size 800mm
- 9m: max boulder size 1200mm

Early attempts to use "in-line" crushers or boulder traps in the discharge pipe were unsuccessful and have therefore nearly disappeared from modern designs.

The amount, size and consistency of the anticipated rock influences the choice of cutterhead configuration and cutter tools. Disc cutters are the most effective tools for excavating hard rock. However, the cutting tools for handling rocks and boulders with a Mixshield require different features in order to operate under pressurised slurry conditions. In particular, the cutter seal and seal gap design differs, to effectively prevent the penetration of muck and slurry (mud packing), but also provide the least possible friction to ensure the cutters are rolling properly across the tunnel face. For face pressures above 4 bar, compensating disc cutter systems have been developed that can handle high outside pressures as well as significant pressure variations, which on a 12m slurry machine is in the range of 1.5 bar from crown to invert.

If rolling is restricted due to inner friction, or the cutter is jammed, it will no longer be available for regular excavation and will only grind on one side. Two-ring cutters provide a better performance at lower single-ring thrust capacity, as they enable several cutting or face contact patterns for the same number of bearing seals and therefore a better relationship between cutting ring- and inner friction. The use of two-ring cutters also requires fewer housing positions on the cutterhead and, for this reason, provides more options for cutterhead openings to

optimise muck flow.

In many cases, the use of two-ring cutters in the inner face and centre area and single-ring cutters for outer face and periphery area is a good compromise. Grain size limiters in the muck openings are installed to keep loose rock or large boulders at the tunnel face, so they can be broken down by the cutters. The design and layout of the size limiters has to be decided on the basis of anticipated ground conditions and installed crusher capacity. Special care also has to be given to the working levels of the different tool types on a mixed face cutterhead. Disk cutters should be positioned 30mm to 50mm ahead of the soft ground tools to ensure that hard rock or boulders are first attacked by the appropriate tool type.

Positive results have been achieved on several mixed face slurry machines using specially designed Monoblock cutters, with a reduced risk of secondary wear to non-cutting related elements of the cutters, such as split rings or hubs.

The combination of mixed face cutterhead tool arrangements and jaw crusher-suction grill arrangements has proven effective when dealing with variable face conditions or cobbles and boulders. The need to manually intervene in order to remove or split boulders has been reduced dramatically and can be considered an exception these days.

Clogging risks

The problem of clogging can be addressed in several ways: choice of tools, quantity of fresh suspension supply, flushing and/or agitation systems in the excavation chamber, flow in the chamber and the geometrical design and shape of cutterhead, excavation and pressure chamber.

The preferred method in adhesive ground conditions is the use of wide cutting tools, in order to achieve bigger cuttings or clay chips. This also reduces the number of tools required to cover the full face. The use of fewer cutting tools increases the free areas between the individual tool sockets and therefore reduces the risk of "bridge building" and adhesion at the cutterhead.

A high circulation or flushing quantity in the excavation chamber, in combination with a suitable cutterhead design, encourages free flow of excavated muck and reduces the time cuttings remain in the chamber to a minimum. Optimisation of the flow and a reduction in the time taken for muck to pass through the excavation chamber also have positive effects on wear reduction. This was demonstrated on the CTRL's Thames Tunnel drives, in London, where two Mixshields were used to mine through chalk layers containing a large amount of abrasive flint.

Flushing nozzles at the centre of the cutterhead supply fresh suspension close to the tunnel face where the soil excavation takes place. These feed lines in the rotating cutterhead are supplied via single or multiple channel rotary joints in the cutterhead centre. Feed line outlet arrangements in front of the submerged wall ensure a sufficient quantity of supply to the rear face of the cutterhead in the excavation chamber. For Mixshields operating in adhesive ground, there is a general tendency to feed fresh suspension in front of the submerged wall.

Each individual supply line into the excavation chamber or the cutterhead can be controlled from the TBM's cabin, with information about the flow and pressure of each individual line being fed back to the operator. Depending on the ground and the direction of cutterhead rotation, adaptation and optimisation of the feed-line flushing pattern is also possible. The installation of mixing arms behind the cutterhead is also a common solution to assist flushing.

There are two ways to avoid adhesion or muck settlement in the pressure chamber area. Mechanical agitator wheels in the invert area can assist muck flow. Alternatively, rotary sizers (see p39) can be used to cut clay chips to size, while not obscuring continuous conveying into the suction pipe. Additional flushing nozzles in the pressure chamber can also assist flow. T&T

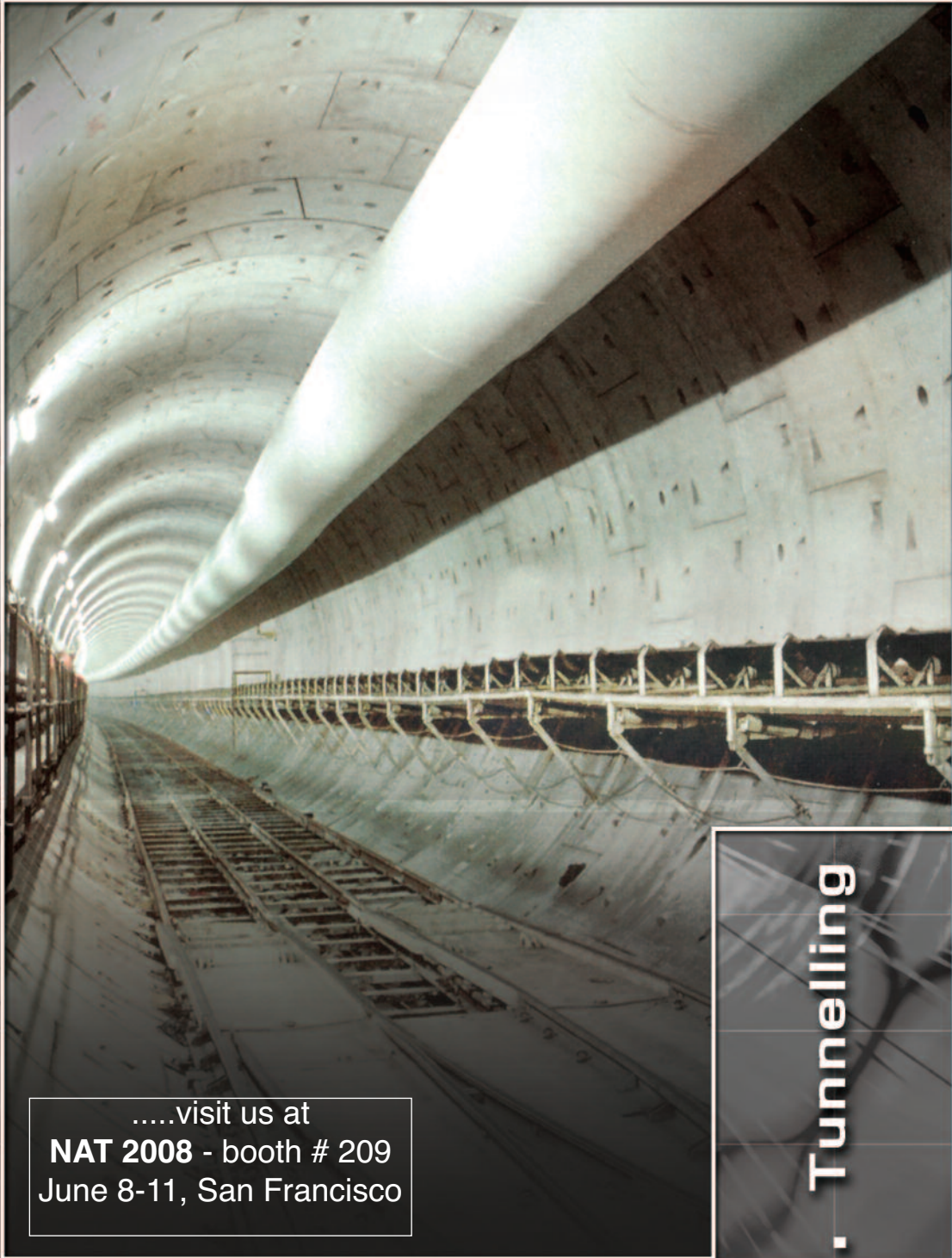
Part 2 of this article, due to be published next month, will focus on potential future developments of Mixshield technology.

REFERENCES

1. B Maidl, M Herrenknecht & L Anheuser, 1996. "Mechanised Shield Tunnelling" Ernst & Sohn
2. W Burger, 2007. "Design Principles For Soft Ground Cutterheads" Proc. RETC 2007, Toronto
3. W Burger, 2006. "Hard Rock Cutterhead Design" Proc. NAT 2006, Chicago



CONTINENTAL
CRUSHING & CONVEYING
A Joy Global Inc. Company



.....visit us at
NAT 2008 - booth # 209
June 8-11, San Francisco

..... Tunnelling

The Global Force in . . .

A World Leader in Conveyors and Conveyor Technology

Continental Crushing & Conveying

West Quay Road, Sunderland Enterprise Park, Sunderland, SR5 2TD. UK

Tel: +44 (0)191 516 5353 Fax: +44 (0)191 516 5399 E-mail: sales@continental-conveyor.co.uk

www.continental-conveyor.co.uk



Total Protection Extreme Reparability

The Flag's tunnel waterproofing systems guarantee maximum impermeability and total reparability

Flag waterproofing membranes guarantee high-quality hydraulic sealing in tunnels as well as underground works. Flag waterproofing systems offer a unique approach to repairing any instance of water or liquid ingress throughout the life of the products; the system can be completely re-sealed without the need to carry out expensive and intrusive demolition.





Above: BASF UGC's Roadrunner mechanised spraying equipment can be used for Masterseal waterproofing membrane application as well as shotcreting.

Performing seals control hazard

Ensuring a completely waterproof tunnel for its entire design life can be an expensive and inexact task. Maurice Jones looks at the latest techniques to make sure tunnel users don't get their feet wet

In many cases ground treatment before excavation will be more economic than water problem rectification by grouting or other methods.

Economical cementitious grouts, perhaps with additives, may well be adequate for grouting where there is little water movement and for larger cracks and cavities. If grouting is carried out before excavation the chances of water movement, and thus washout of the grout before curing, are lower due to minimal pressure differentials. If a full grouting programme of the surrounding ground has been carried out to seal the excavation, water ingress may no longer be a problem. Nevertheless grouting of the rear of the lining is valid for both structural and water-control properties, especially where there is an annular gap such as behind a pre-cast lining.

Although more expensive, grouting with synthetic materials, otherwise known as chemical grouts, should be more effective in higher grout water pressures and water flows, as well as being more able to penetrate finer fissures and the pores of fine sands, for example. The Orica-group Minova Carbotech range of ground-injection grouts are based on polyurethane and organo-mineral resins, and acrylates as well as

microcements, all of which are designed for use in high groundwater pressures, depending on other conditions.

Even with the best laid plans for designing in waterproofing, the circumstances of construction may make corrective waterproofing necessary. For example in construction of the recent cut-and-cover tunnel for Hamburg's new airport terminals, the excavation was supposed to be protected by diaphragm walls. However, one section of wall leaked, carrying soil into the excavation and breaking a high-pressure water pipe in the process, damaging an access bridge. Contractor Brückner Grundbau stabilised the ground and sealed the water leaks by drilling Minova Wiborex bolts from the surface into the affected area and injecting through them with Minova CarboPur WT and CarboPur WFA fast reacting resin grouts. During removal of the debris, the area was again injected with CarboPur WFA through injection lances. Normal construction could then proceed under dry conditions.

Tecinest of Wommelgem, Belgium, produces a range of grout products under the Spetec trade name for waterproofing, crack injection, cavity filling and sewer repair



Above: Switzerland's Collombey tunnel, showing waterproofing membrane covering the crown and UGC's Masterseal sprayed on below groundwater level

as well as rock anchors and soil stabilisation. These include mono- and multicomponent resins including low viscosity (110cPs) forms for better penetration. These exhibit another feature of 'chemical' grouts, that of flexibility that allows the grout in situ to accommodate possible ground movements after curing. According to Tecinvest the Spetec PU 52 LowVisco 2-component, solvent-free grout can be used to create a waterproof membrane by injection, with a typical reactivity time of 20 minutes.

Concrete solutions

Structural concrete used in tunnel linings is generally of low water absorbency (not more than 2% according to the BTS Specification for tunnelling) but various approved mix ingredients and additives can be used to improve concrete's inherent impermeability. However concrete and its aggregates are subject to shrinkage cracking. Even though sample testing can assess the extent of shrinkage, this still has to be taken into consideration when assessing possible permeability. Loading may also cause further cracking and increased permeability.

The Sika ViscoCrete range of concrete additives are designed to impart specific properties to concrete for both casting and spraying, including the improving of impermeability by reducing the possible water/cement ratio. Means of reducing concrete permeability, and also improve related properties, include reducing the water/cement ratio, but where pozzolanic

COMMITMENT. THE DETAIL WHICH MAKES THE DIFFERENCE.

MAPEI Underground Technology Team

MAPEI Underground Technology Team is MAPEI's answer to the needs of those who work in the world of underground construction – it's the result of MAPEI's investment into the research & development of specific products, of MAPEI's commitment and devotion of its team who embody professionalism and experience. Because commitment makes the difference. By your side from the beginning to the completion of the project.

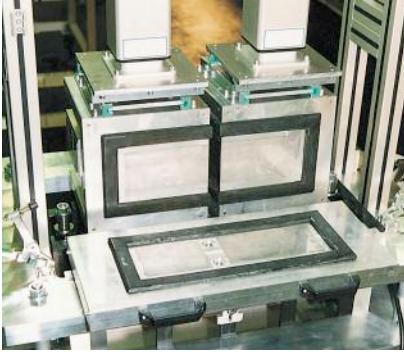
- ✓ **Intervention capability anywhere in the world within 24/36 hours**
- ✓ **Production increase**
- ✓ **Cost reduction**



UNDERGROUND TECHNOLOGY TEAM



www.utt-mapei.com



Above: Segment gasket seal test equipment in the Phoenix laboratories



Above: Installing Phoenix drainage joint seals in the Dichtungen Tunnel

materials are available at reasonable costs they can be used as a substitute ingredient. Microsilica can be used in cast concrete to reduce permeability, but also in sprayed concrete to improve bonding and reduce slump. In fresh-sprayed concrete, microsilica can reduce permeability to prevent aggressive agents from penetrating and attack the concrete and reinforcement, improving sulphate and chloride resistance.

A proprietary manufactured form of pozzolanic material from Norway is Elkem Microsilica. Elkem Materials is the world's leading microsilica supplier. The design life of tunnel concrete in these applications is at least 100 years with minimal maintenance.

Membranes

Plastics membranes are one of the most widely used means of comprehensive tunnel waterproofing. Although forming an impermeable barrier careful, skilled installation is necessary to ensure that the membrane is adequately supported to withstand expected water pressures, ensure that no sharp rock or other objects penetrate the membrane causing leakage paths, and to ensure securely sealed joints between adjacent sheets. Penetration problems can



Above: Daetwyler Rubber CoexSwell segment gaskets with integral swelling compound used on pre-cast concrete waiting installation on the Marmaray Tunnel's bored section

be alleviated by good surface preparation, application of a sprayed concrete smoothing layer, or the installation of an outside fleece layer that can also offer drainage paths.

The Sika group has a wide range of composite and non-layer membranes depending on the performance required. At the simpler end of the scale Sikaplan-14.6 III-Tunnel is an unreinforced, plasticised PVC membrane for cut-and-cover tunnels. It is resistant to common aggressive elements in groundwater and soil, including soft water. It can be welded with hot air 'torches' and can be used on damp or wet substrates. The top (signal) layer is coloured yellow and the bottom layer dark grey.

A waterproofing geocomposite membrane manufactured by Flag of Bergamo was used in the rehabilitation of La Contessa Tunnel, Perugia, Italy for the ANAS national road administration. The tunnel had suffered from high water circulation on the permeable arenaceous ground. The membrane was installed in unlined sections together with internal cladding. Water control measures also included the laying of 50mm-diameter drainage pipes. In a 94m-long cut-and-cover section waterproof mortar was supplied by Kimia of Ponte Felcino

Sprayed on

The choice of sprayed concrete for primary lining, and sometimes, permanent lining, can present particular problems in water conditions. Whilst bonding can be improved by careful mix design for low slump and high bonding, water flows that are not under high pressure can be combated by grouting or channelling to a drain. Drain passages can be formed by specialised dimpled linings, nonwoven textile fleeces or channel covers such as the Sika Aliva system placed over

cracks and other water inlets. In these ways a dry surface is preserved to facilitate easier sprayed concrete application. The drainage channels may be incorporated into the lining, but are more often made redundant by an injection grouting programme, or the installation of a full-profile membrane.

Another approach to channelling in the permanent lining is to form channels in planned joints. Phoenix supplies 100mm-wide drainage joint seals for this purpose to keep water within the channel.

One of the most significant developments in tunnel waterproofing in recent years has been the introduction of reliable synthetic spray-on membrane systems as an alternative to installing sheet membrane (*T&T* Sep. 2007 p35-37). Sprayed membranes can be used easily on irregular profiles and in locations, such as junctions and services chambers where lining with sheet membranes would be laborious. Existing services could be covered up during application, whereas they would have to be removed for sheet membrane installation or the membrane installed around them. Sprayed membranes are also more tolerant of rough rock surfaces. For more regular profiles sprayed membrane application can be carried out using the new robotic spray units as used for sprayed concrete.

In a recent application of UGC's Masterseal 340F sprayable membrane it was combined with sheet membrane in the Collombey road tunnel in Switzerland. The lower part of a drill-and-blast section of this tunnel lies below groundwater level where the engineer preferred to use Masterseal rather than the PVC membrane used in the upper part of the profile since the lining below groundwater level would be subject to full water pressure. This lining was applied

using a UGC Meyco Roadrunner mechanised spray system. The sheet membrane represents a drainage system with pipe collectors installed in both sides of the tunnels. In a cut-and-cover section a bitumen membrane was used for waterproofing. The contractor was a Murer and Züblin JV with the Scandinavian Rock Group as specialist sub-contractor.

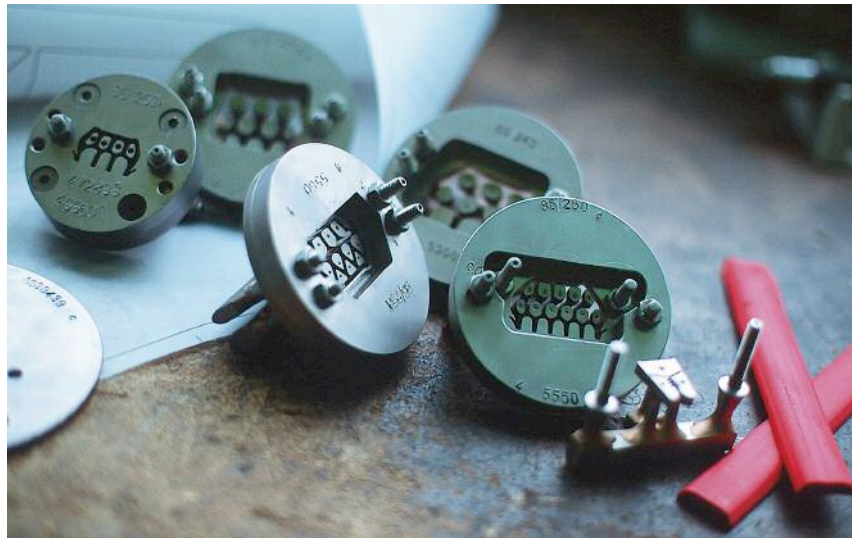
Special conditions included a relatively low ambient temperature of 3-6°C necessitating application of the Masterseal 340F in two or three thin layers to ensure proper curing. These were applied on a 'smoothing' layer of 4mm-thick sprayed concrete. Where local seepage areas of bare rock were present Masterseal DR1 drainage fleece was applied to present a dry surface for spraying. Use of sprayed membrane ensures that there is no migration along the membrane/substrate interface, lessening the risk of seepage, although any eventual damage is easy to repair says BASF UGC.

SikaProof SB is a 2-component, bitumen-based, spray applied waterproofing membrane for seamless waterproof of below-surface structures such as cut-and-cover tunnels and basements. A catalyst reacts with a polymer-modified bitumen emulsion in mid-air, causing it to break down cure. The material is non-toxic, odourless and approved for use with potable water.

Gaskets and seals

Whilst offering remedial grout systems as with many other suppliers, Rascor emphasises various preventative waterproofing systems for vulnerable sites in the tunnel structure such as construction joints, and movement and expansion joints. Preventative waterproofing now accounts for over 80% of the Company's turnover. Systems also include injectable seals for joints and services glands through walls, plus dummy joints for crack control. Developed for basement waterproofing but also applicable to cut-and-cover tunnelling and similar methods, Rascor's integral White Tank system is designed to replace use of bitumen for waterproofing concrete structures that Rascor claims is largely obsolete. This system utilises the concrete structural elements themselves as the basis of the waterproof barrier. Additional joint seals and waterproofing grouts may be needed if concrete quality is not sufficient.

Where any form of jointed lining is used, whether pre-cast or cast in situ, it is vital to seal these joints to prevent leakage, and maybe also to cushion the effects of subsequent movements after construction. Specialist manufacturers produce many standard designs of gasket seals, and if required, custom-designed profiles. Leading suppliers include Phoenix of Germany (part



Above: A collection of profile injection moulds from Daetwyler Rubber

of ContiTech AG, the Continental Group) and Dätwyler of Switzerland. Designs vary according to factors such as expected pressure, the design and size of the joint, the means of installation and the nature of any water contamination.

Phoenix now has access to a broader range of elastomer expertise in the Continental Group from other industrial sectors to combine with its long expertise in profiles and gaskets for segmentally lined tunnels, cut-and-cover excavations and pipe jacking. Compression sealing gaskets are available for both concrete and steel cast lining segments in a range of over 50 standard sections. Recent transport tunnel projects supplied include the Netherlands Groene Hart Tunnel; the Hallandsastunnel, Sweden; and the Metro Dubai Red Line.

Within a list of recent Phoenix innovations there are an anchored seal installed during concrete segment production, and one, called the 'Evolution Seal' that combine a hydrophilic swelling strip within a compression seal, provided even more and early security against water passage. The anchored seal was developed in conjunction with the contractor Hochtief and TBM manufacturer Herrenknecht. Using this process gasket installation is not only a factory process but also becomes more efficient without costly gluing and reducing environmental impact.

Dätwyler recently entered into a new partnership with Vertex of Mogadore, Ohio for the manufacture of cast segment seal frames and corners. In the US the group holds patents for gasket technologies in prefabricated concrete construction and synthetic and concrete pipes. The first project to be delivered with gaskets was the Brightwater Treatment System East in Seattle for the 5.08m-diameter, 4.2km-long tunnel. The 2,800 segment rings require 17,000 sealing 'frames' with 68,000 vulcanised corners. Others scheduled for supply of seal corners include the North Dorchester Bay CSO Storage Tunnel and the Allegheny River Tunnel in Pittsburg.

Watertightness must also be a consideration for sewers and vertical structures. In the first water ingress may load pumping systems excessively whilst creating possible long-term structural security and environmental problems. In vertical structures, especially those that cross the water table, water pressures may not be high but the possibilities of 2-way flow can present possible structural problems by removal of soft and small-grain ground that surrounds the structure. A recent introduction in this field has been the new CSD Plus 3 manhole seal from Theodor Cordes, a manufacturer that is also a distributor for Phoenix. These prelubricated seals have an integrated vertical force element that locks the gap between manhole ring. The seal is easily installed on the spigot and the vertical force transfer element ensures accurate location without reworking the gap, and also reduces pollutant attack on the main seal. No mortar is required. The seal itself is made from styrene-butadiene-rubber (SBR), which is proven in surface water and sewerage applications. An integrated self-sliding 'leap' protects the main seal against damage and limits horizontal shear stress on the joint.

Sika has also introduced a manhole compression sealing strip made of 16mm-diameter, preformed butyl rubber. It can also be used with pipes, gutter drain joints and lightweight precast panels. The seal is permanently flexible and non-shrinking.

Joint sealing using low-pressure injection guns is facilitated by having a secure, uniform, base to the rear of the joint to save on material and assist full treatment of the joint itself. The new Sika PEF backing rod can perform this function. It is weather resistant, easily compressible and does not absorb water itself. A wide size range is available in lengths of 20 or 50m. Once in place the gun-applied sealant is applied. This may be elastomeric or a self-expanding polyurethane foam. Neither will adhere to the backing rod, ensuring unrestricted movement of the sealant.

T&T

Classified

RECRUITMENT



Building success requires a reliable partner

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

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

E-mail: info@tunnelcrew.nl

www.tunnelcrew.nl

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

Like our beaches, the opportunities in Dubai are endless.

Al Naboodah Construction Group is renowned as one of the leading contractors in the UAE and with business thriving, Al Naboodah Specialist Services has been set up to fill a niche in the booming Gulf market. This prominent contractor now requires the following specialist construction professionals to complement the existing Western management team across the UAE.

Ground Engineering Division

- **Contracts Manager and Contracts Engineers** - Graduate Engineers with experience in some form of ground engineering preferably with jet grouting, earth retaining structures, soil improvement or piling/ground anchors.

Microtunneling & Directional Drilling Division

- **Microtunneling Superintendent** - Experience of pipe jacking using Herrenknecht machines and ideally some directional drilling.
- **Site Agents / Contracts Engineer** - Graduate Engineers with experience in microtunneling / pipejacking and / or directional drilling.
- **Plant Superintendent** - Experience in servicing / maintenance of rotary drilling rigs, power packs, hydraulic systems, grout pumps and bentonite systems as well as general supervision of workshop facility.

The company offers a challenging and rewarding environment to those looking for a long term career growth with the company and to build up a strong top management team with the objective to develop and expand the business into other specialist construction activities.

To register your interest in these unique opportunities, contact our retained consultant, **Matt Tomlin** on + 971 4 299 0070 or email m.tomlin@hillmcglynn.com

www.hillmcglynn.com



Hunter Personnel

Specialists in Tunnelling, Civils
and Construction Recruitment.

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

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

www.hunterpersonnel.com




UK & OVERSEAS OPPORTUNITIES



Current opportunities:

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

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



Engineering Geologist – New York £Excellent Package

Face logging and general on-site engineering geology for a major subway construction project. Qualification and proven site experience on a tunnel project.

Senior Design Engineer – London - £45K + Benefits

Civil / Structural design of TBM tunnels, underground stations and major infrastructure projects. Chartered, or near chartered, with major project experience.

Tunnel Shift Engineers – UK - £30K + Car and Benefits

Experience of TBM or NATM schemes, supervising site works on major tunnel construction. Excellent career development opportunities with leading contractor.

For more details of these and other vacancies, please contact **Scott Gisby** by email: scott.gisby@coyles.co.uk or call +44 (0) 1622 772509.

www.coyles.co.uk/tunnelling



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

WEBSITE DIRECTORY



AGI

DSI SOPROFINT **DSI**

DYWIDAG-SYSTEMS INTERNATIONAL

GROUND CONTROL SOLUTIONS
www.dsi-tunneling.com



MINOVA

Minova CarboTech GmbH

Waterproofing - Consolidation - Bolting

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



PALMIERI
TUNNELLING - DRILLING

CUSTOM-MADE CUTTERHEADS FOR TBMs
MICROTUNNELLING AND VERTICAL OR
DIRECTIONAL DRILLING MACHINES.
BACK UP AND MUCK HAULAGE SYSTEMS.
ROLLING STOCK AND SPECIAL TUNNELLING
RELATED EQUIPMENT.

PH. +39 0565 857127
FAX + 39 0565 856152
sales@palmierirocktools.com
www.palmierigroup.com



Tunnel Estimating Services

A comprehensive estimating service for all tunnelling, pipejacking, shaft sinking and open cut works. Database building for all engineering disciplines using the CCS system

Tel: +44(0) 1785 661783
Tel/Fax: +44(0) 1785 664111
Mobile: +44(0) 7946590148
roger.finch@tunnelestimateservices.co.uk
www.tunnelestimateservices.co.uk

Sp SPECIALIST PLANT

TUNNELLING EQUIPMENT HIRE & SUPPLY

Specialist Plant Associates Ltd

Agents for **CIFA**

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

Tunnel, Caisson & Cavern

BABENDERERDE ENGINEERS

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

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

Germany, USA, Brazil

www.babeng.com

TPC Tunnel Software

DTS
DESIGN & TECHNIC SINGAPORE

Total Tunneling Solution

10 units of Used Schoma Locomotives Available
(Model: CFL-180-DCI)

T: +65 6515 1970
F: +65 6515 1971
Email: info@d-t.sg
www.d-t.sg



SCHAUENBURG
TUNNEL-VENTILATION GMBH

Flexible Ventilation Ducting

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

MASCHINEN - UND STAHLBAU **LSB DRESDEN**

NIEDERLASSUNG DER HERRENKNECHT AKTIENGESellschaft

Your partner for special solutions in the tunnelling sector.

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

ALAN AULD ASSOCIATES
CONSTRUCTION CONSULTANTS

TUNNEL AND SHAFT SPECIALISTS

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

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



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

tunneltrade.com
your tunnel internet portal

ABG ENVIRONMENTAL GEOSYNTHETICS

CAVIDRAIN

Groundwater Drainage for Tunnel Walls & Invert

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

F TRANSFORGE UK LTD

Tunnel Steelwork Specialists

Cable & Pipe Brackets and Walkways
Sleepers and Accessories

+ 44 (0) 1572 787 504
info@transforge.co.uk

Geotechnical Instrumentation

Products for monitoring tilt, displacement, pressure, and strain. Data acquisition and remote, web-based monitoring systems.

SLOPE INDICATOR
www.slopeindicator.com • solutions@slope.com
Tel: +1-425-493-6200

DGSI
DURHAM GEO SLOPE INDICATOR

QA PHOTOS

'Experience in depth'

Tel: +44 (0)1303 894141
Fax: +44 (0)1303 894144
Email: pix@qaphotos.com
www.qaphotos.co.uk

HERRENKNECHT



Tunnelling Systems

www.herrenknecht.com



www.lovat.com

H+E

H+E LOGISTIK GMBH

www.helogistik.de

VMT

www.vmt-gmbh.de

vidaLaser

Custom design and manufacture of tunnel laser

Visit our website for datasheets and application notes

www.vidalaser.com

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

Dates & Events

20-22 MAY

Intertunnel 2008 Turin, Italy

This bi-annual international exhibition will focus on major projects in Italy. The show promises to be an excellent networking environment. Contact: Olivia Griscelli, exhibition director: email: intertunnel@mackbrooks.com; web: www.intertunnel.com

29-30 MAY

Second Seminar of CPT "Tunnels and Underground Works in Portugal", Lisbon, Portugal

Assessing the country's industry potential, this seminar is organised by the Portuguese Committee on Tunnelling (CPT). Contact: Catarina Luis. Tel: +351 218443859; email: spg@lnec.pt; web: www.spgeotecnia.pt/cptuneis

30 MAY

Workshop on "Planning of construction of tunnels for high speed railway connection AIS, Slovenia

Organised by the Slovenian Society for Underground Structures the conference takes place at the Congress Centre Portus, Hotel Slovenia, Portoroz, Slovenia. Contact: Tel: +386 1 470 4610; web: en.ita-slovenia.si

3-6 JUNE

International No-Dig 2008 Moscow, Russia

Hosted by the International Society for Trenchless Technology and co-hosted with the Russian Society for Trenchless Technology, this will be the first ISTT event to be held in Russia. Contact: ISTT; Tel: +44 20 7259 6755; email: info@istt.co.uk; Web: www.istt.com

7-11 JUNE

North American Tunneling Conference San Francisco, USA

The 2008 NAT Conference will be held at the Hyatt Regency, San Francisco. Conference programme and registration details are now available on the UCA of SME web site. Contact: Society for Mining, Metallurgy and Exploration (SME); www.smenet.org

10-12 JUNE

Swiss Tunnel Congress 2008 Luzern, Switzerland

The annual review organised by the Swiss Tunnelling Society includes a lecture on grouting as a support measure during excavation, and an excursion to the Gotthard Tunnel. Contact: Thomi Bräm; Tel: +44 56 2002333; email: sia-fgu@swisstunnel.ch; web: www.swisstunnel.ch

23-25 JUNE

2nd Brazilian Congress of Tunnels and Underground Structures, Sao Paulo

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

23-27 JUNE

Course on "Tunnel Design and Construction, Brunel University, UK

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

25-27 AUGUST

Wireless Communication in Underground & Confined Areas Québec, Canada

The second international conference focusing on original research, innovative applications, or analysis of experiments on site, relating to the niche market of telecommunications in an underground environment (tunnels, metros, mines, etc). Contact: web: www.icwcuca.ca

10-12 SEPTEMBER

12th International Conference "Geotechnica 2008 - Geotechnics, Slovak Republic

The conference organised by the Technical Universities of Ostrava (CZ), Kosice (SK), and Gliwice (PL) focuses on techniques, technologies and monitoring of geotechnical construction. Contact: Nora Badiková. Tel: +421 (0)2 659 36 486; email: orgware@mail.t-com.sk

22-27 SEPTEMBER

2008 ITA World Tunnel Congress Agra, India

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

23-26 SEPTEMBER

InnoTrans 2008 Berlin, Germany

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

6-8 OCTOBER

International Congress 'Building Underground for the future,' Monaco

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

22-24 OCTOBER

Underground Infrastructure of Urban Areas, Wroclaw, Poland

The conference is organised by the Urban Engineering division of the Institute of Civil Engineering, Wroclaw University of Technology, in association with the ITA, ISTT and EFUC (European Forum on Underground Construction). Contact: tel: +48 71 320 2914;

BRITISH TUNNELLING SOCIETY

19 JUNE: TUNNEL OPERATIONS

Fire Engineered Solutions for Road Tunnels. A discussion on the effect of tunnel fires and how active fire fighting systems offer the opportunity to improve safety for users, protect the tunnel structure, and enhance the safety of emergency response crews. Presented by Tim Healy (Capita Symonds), John Celentano (Mouchel), and Les Fielding (London Bridge Associates) - 5.30pm, for a 6pm start, at the ICE, Westminster, London. NB: Summer break follows.

email: andrzej.kolonko@pwr.wroc.pl; web: www.bliw.wroc.pl/ulua/2008

27-28 OCTOBER

20th National Conference, Tunnelling Technology & The Environment Niagara, Ontario, Canada

Organised by TAC, the Tunnelling association of Canada. Contact: +1 604 629 1736; email: info@tunnelcanada.ca; Web: www.tunnelcanada.ca

10-12 NOVEMBER

ICDE 2008, Challenges and Risk Management of Underground Construction, Singapore

The International Conference on Deep Excavations (ICDE) is an ITA sponsored event organised by TUCSS. It aims to be a forum for contractors, engineers and owners to share and discuss experience. Contact: TUCSS; email: info@tucss.org.sg

23-28 MAY 2009

2009 ITA World Tunnel Congress Budapest, Hungary

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

A DATE TO REMEMBER...

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

DEPUTY EDITOR
Amanda Foley
Tel: +44 20 8269 7789 Fax: +44 20 8269 7840
Email: afoley@wilmington.co.uk

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

DESIGN
Natalie Kyne

TECHNICAL ILLUSTRATOR
Nick Stenning

PRODUCTION CONTROLLER
Loraine Lee
Tel: +44 20 8269 7799 Fax: +44 20 8269 7840
Email: llee@wilmington.co.uk

ADVERTISING

GROUP ADVERTISEMENT MANAGER
Gary Tween
Tel: +44 20 8269 7849 Fax: +44 20 8269 7840
Email: gtween@wilmington.co.uk

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: dwwildman@wilmington.co.uk

HOW TO SUBSCRIBE

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

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

HOW TO GET BACK ISSUES

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

HOW TO GET REPRINTS

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

REPRO/PRINT

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



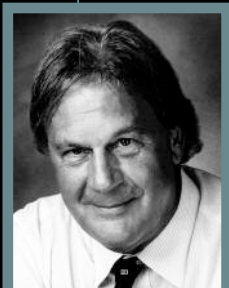
Tris Thomas



Amanda Foley



Gary Tween



David Wildman



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; Paul Hoyland CEng, MICE; Tom King CEng, FIMMM; Richard Lewis CEng, MICE; Roger Margerison BSc(Hons) CGeol FGS; Barry M New MSc, PhD, CEng, MICE; Andrew Smith CEng, MICE; Ivor Thomas CEng, MICE; Nathan Wilmot MEng ACGI CEng MICE MHKIE; Eddie Woods BSc, MICE, HKIE

No TBM company in the world has more.

Experience.



More years. More projects. More kilometers of tunnel completed.

The numbers say it all. 50 years, 3500 km of tunnel, 700 projects completed worldwide. In fact, Robbins machines have bored more tunnel, and our cutters have excavated more hard rock, than any of our competitors.

It is not just the quantity, but the quality of Robbins' experience that sets us apart. We've been the supplier of choice for some of the most demanding projects in history. The greatest geological problems and environmental challenges.

The longest tunnels. The most remote locations in the world. If it can be imagined, Robbins has the experience to make it a reality. Learn more.

Visit us at www.robbinstbm.com.

Robbins 