

JUNE 2010

# tunnels & tunnelling INTERNATIONAL



7



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## Special report: Australasia

T&TI reviews the tunnelling work load throughout Australasia and takes a close look at Melbourne's sewer upgrades

## Technical: Control systems

T&TI looks at the developments in tunnel control systems

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## Cutting through the Alps

A look at the Sedrun drive of  
the Gotthard base tunnel






## AUSTRALIA: MORE DRINKING WATER.

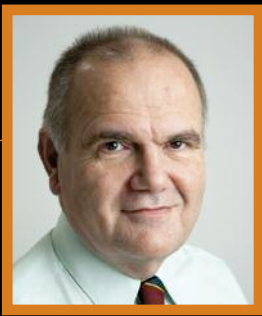
Australia consists of 80 percent of dry, desert-like areas and suffers from long periods of drought. Desalination plants are the solution to secure the drinking water supply in the densely populated coastal areas in the south and southeast.

A total of 11 Herrenknecht machines – with diameters ranging from 2.38 to 4.71 meters – have been working for the construction of four Australian plants and their linkup to the drinking water system. In Sydney, for example, two hard rock machines of the type TBM3400XH have completed an inlet and outlet tunnel, each with a length of 2.5 kilometers using the segmental lining method. At the same time, two machines of the type AVND2000AB and one EPB2000TB provided for the linkup of the plant to the urban water supply network using the pipe jacking procedure. In Wonthaggi, in the southeast of Melbourne, the two S-562 and S-563 Mixshields will excavate a total of 2,650 meters of inlet and outlet tunnel right down to beneath the seabed.

Already today, around half the world's population live in coastal areas – and this trend is rising. Modern desalination plants contribute decisively towards meeting their drinking water needs. The required underground water tunnels can be produced quickly and safely with Herrenknecht technology.

AUSTRALIA	
PROJECT DATA	CONTRACTOR
 <b>Sydney</b>   2x TBM3400XH, 2x AVND2000AB, EPB2000TB   Diameters: 2,380 to 4,160mm   Total tunnel length: 11,354m	John Holland Pty. Ltd., MCB Partnership
<b>Wonthaggi</b>   2x Mixshields   Diameter: 4,710mm   Total tunnel length: 2,650m	Thiess Pty. Ltd.
<b>Tugun</b>   2x AVN2800AH   Diameter: 3,400mm   Total tunnel length: 4,200m	John Holland Engineering Pty. Ltd.
<b>Adelaide</b>   2x AVN2800AH   Diameter: 3,440mm   Total tunnel length: 2,456m	McConnell Dowell Constructors Pty. Ltd.





## comment

# Why the same old, same old

The BTS meeting report of a presentation earlier this year from Bifinger Berger engineers includes a brief history of the construction of the first Gotthard rail tunnel. It shows that harsh contract conditions foisted on contractors that are desperate enough to want the work is far from a new phenomena. For whatever reason, Louis Favre accepted a fantastic time frame, had virtually nil local geotechnical knowledge and low budgets, with the seeming inevitable consequences of project cost and schedule overruns and Favre's own demise before project completion. In those days before establishment consideration of working conditions, the tunnellers suffered badly too.

There have been many moves in recent years to improve the smooth running of contracts once awarded with such measures as geotechnical baseline reports, better risk apportionment, and client-contractor 'partnerships'. This is a subject that T&T will return to soon. However, sceptics might ask, with contractors always looking for the next source of work, would they not always claim that client-contractor partnerships always work well?

Whatever the case with awarded contracts, it appears these days that some of the biggest delays and unnecessary costs occur before contracts are awarded. These not only involve the client, or its funders (such as taxpayers), in extra costs, but also those who have to answer requests for expressions of interests, and prequalification. Such procedures involve established contracting companies in substantial expense, which may never be recoverable. Such preparation costs are increased if it necessary for several companies to come together in a joint venture to accumulate and offer the necessary expertise, equipment, finance and local knowledge.

For their part it is well known that contractors have had a historical tendency to bid low and try to make money on 'unforeseen circumstance', of which there can be many in underground construction. This appears to have led to mistrust amongst clients and a tendency to try and be cleverer in a battle of wits. And yet, if there is an agreed costing of a bill of quantities, and a careful inspection of necessary extra work needing to be undertaken, there should not be a real problem. Despite its history of difficulties, the Hallandsas rail tunnel projects (see T&T May 2010) should be a case in point.

Let T&T insert an idea into the mix. It may not even be new but is surely worth discussion. The clients of many projects that have hit difficulties, whether financial geological or environmental, have appointed a supremo to kick a few posteriors and get things moving again. The most successful have a history in civil engineering, mining or major project management already. When the project leader is fair to all those involved in the contracts, this has led to an increase or at least a maintenance of respect towards this leader. Far from being a figurehead, the project leader must be prepared to 'get hands dirty' and find out everything that is going, or not going on, so that all obstacles to project completion can be removed.

This project leader should be appointed before any construction contracts are let, and consulted on what contract procedures and client requirements are practical. He or she would then lead the appointments of those that will be entrusted with carrying out the work, whether individuals or contractors, within the agreed budget.

Whether or not this is fanciful, hopefully such a project structure would allow those involved to 'get on with the job', and deliver what the client wanted in the first place, within the specified project period and at budget cost. Nevertheless the concept planning, investigation and design processes should also be speeded up without contractors having to incur speculative expenditure through free design advice, joint venture formation, or similar measures. While some consultancy is, of course, necessary, it does not actually get the job done, but does add to costs.

There are several successful projects around the world that have shown that cost and schedule overruns are not inevitable but have delivered valuable infrastructure that may not be perfect, but works well. Whatever the way forward, it is clear that more trust is needed if major project management is not to get a bad name, with consequent drying up of funding for future work.

Maurice Jones



### On the cover

T&T looks at the Sedrun drive of the Gotthard Base Tunnel cutting through the Alps



### On the back

T&T Asia launches with a look at the construction of China's metros

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# TUNNEL WITH CONFIDENCE START TO FINISH...



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## AND BEYOND

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# LOVAT

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# Leaks or not in immersed tube

## VIETNAM

**V**oids between concrete and the bolts as well as piping, installed to blow sand under the tunnel bottom to keep the tunnel fixed in future, have been identified as the cause of seepage in Vietnam's Thu Thiem immersed tube tunnel.

Damp patches and moisture found in the first two elements of the tunnel are not serious and will not affect the quality or completion of the work currently under construction beneath the Saigon River in Ho Chi Minh City (HCMC), claimed Oriental Consultants, the consulting supervisor for the project.

This was at a meeting on 25 May with city leaders, including the city

People's Committee chairman Le Hoang Quan and permanent deputy chairman Le Thanh Tai, as reported by local media. According to Oriental Consultants the leak patches, measured at  $2\text{ml/h/m}^2$ , are within the permissible levels, which range up to  $5\text{ml/h/m}^2$ .

The company earlier reported that there were 130 damp and wet patches inside the tunnel's first two elements.

Builders installed a host of equipment to the tunnel ceiling, including anchored bolts, used to connect cables with the tunnel section to fasten them to the riverbed.

The Oriental Consultants divided the problems into three levels. The first level is humidity; the tunnel inside is wet making the concrete

surface change its colour. The second level is soakage; moisture is visible and wet to the touch. The third level is leakage; concrete changes colour and water drips down the tunnel walls.

After examining wetness within the tunnel on 27 April, Oriental Consultants explained that the damp patches did not constitute leakage.

Specifically, the first section had three damp patches in the bottom, over 30 wet and damp patches in the ceiling and in 13 locations along the tunnel walls.

The worst conditions are in the second element of the tunnel, with three damp patches along the tunnel floor, and over 50 and 30 weeping and damp patches in the element's ceiling and walls

respectively.

To prove that the weeping patches are not serious, the company said that the seepage had already decreased 50 per cent in the one month since the first section's installation.

East-West Highway management board director Luong Minh Phuc said that the weeping conditions were within permitted levels and all technical problems had been reported to the State Inspection Council.

Thu Thiem Tunnel is the first immersed tube tunnel in Vietnam. It is part of the East-West Highway project in Ho Chi Minh City and will be the longest immersed tube tunnel in southeast Asia.

T&TI tried contacting Oriental Consultants without success.

## Airport Link reaches milestone

### AUSTRALIA

**B**risbane's Airport Link Tunnel project reached its latest milestone last month as the first TBM began to be lowered into a six-storey tunnel launch box at Kalinga Park.

The USD45M Herrenknecht EPB TBM, Airport Link's first of two, arrived in pieces last November and was assembled by a crew of approximately 80 people. The 195m long machine weighs 240t.

Airport Link comprises twin 5.1km road tunnels, and the two TBMs will be used to excavate the tunnels between Clayfield and Lutwyche.

The tunnels are being

excavated using a combination of techniques involving TBMs, roadheaders and cut-and-cover.

The Airport Link project is being constructed together with the Northern Busway (Windsor to Kedron), requiring a total of 15km of tunnels and their connecting ramps.

Fifteen roadheaders are now digging tunnels between Bowen Hills and Kedron. Another two roadheaders have been delivered to worksites at Lutwyche and Wooloowin and will begin work shortly. More than a quarter of the tunnels are now excavated.

In late July the first of the TBMs is expected to begin its 12-month journey from Toombul to Lutwyche. The machines will fit

out the tunnel with its concrete lining as they move forward at about 85m per week.

Queensland Premier Anna Bligh said, "The sections, each weighing between 85t and 105t, are being lowered by a massive gantry crane. In total, two 150t and three 40t cranes are required to lower these massive machines into place."

"Later this month the 12.48m diameter cutterhead, the biggest to ever operate in this country, will be lowered into position," Bligh continued.

On completion in 2012, constructor Thiess John Holland will reinstate the work site at Toombul and return Kalinga Park to the local community.

## News in brief

### Managers escape jail time

Two former managers for Aggregate Industries NE, convicted of supplying substandard concrete to Boston's Big Dig highway project have avoided jail terms. The pair were convicted of 135 felony counts including conspiracy to defraud the government with respect to claims.

### Academy gets approval

The GBP 12M (USD 17.5M) Redbridge Crossrail Tunnelling Academy, which is set to be constructed at Aldersbrook Sidings, near Ilford Town Centre, has been approved by Redbridge and Newham councils.

### Malaysian tunnel on hold

The MYR 9bn (USD 2.7bn) interstate water deal to supply water to Selangor from Pahang in Malaysia by 2014 is stuck because Selangor has not yet given approval for remaining lots of land needed for the construction of a water treatment plant. (See T&T Asia, p5)

## In-Mo Lee is new ITA president

### INTERNATIONAL

**P**rofessor In-Mo Lee has been voted president of the International Tunnelling Association. The Korean saw off

French candidate Yann Leblais and Norwegian Professor Eivind Grov in the second round of voting after not gaining a majority in the first. The election was held in Vancouver at the ITA General Assembly.

The Korean School of Civil, Environmental and Architectural Engineering in Seoul professor will take over from the UK's Martin Knights, who is stepping down after three years in the position.

# Kishanganga TBM launched

ITALY

**I**talian company Seli launched its 400t, 6.18m diameter TBM last month that will be used on the Kishanganga Tunnel project in India. The machine was delivered to the project's main contractor Hindustan Construction Company (HCC) during an official ceremony to mark the company's 60th anniversary at its factory in Aprilia, Italy.

The gold-painted machine will bore 700-1000m under the Himalayas, crossing geological conditions of localised poor and squeezing rock, plus fault zones. The TBM is equipped with eight 315kW AC motors, generating a total cutterhead power of 2520kW,

controlled by a variable frequency drive system.

The gripper shield has 26 holes to allow probe drilling/grouting the rock ahead of the face, while the tail shield has an additional eight holes.

Convergence measurements will be performed continuously during excavation through specific holes in the front shield.

The anniversary ceremony included a visit to the site of the company's under-construction new factory and concluded with a special brunch attended by T&T. The new site will boost the TBM production capacity from today's eight units per year to over 20 units, with boring diameters up to over 15m.



**Above:** The gold painted TBM was launched at Seli's 60th anniversary celebrations in Aprilia

## Lake Mead TBM unveiled

USA

**T**he TBM that will mine a third 4.83km raw water intake in Las Vegas was unveiled last month. The 6.36km diameter Herrenknecht machine, that will bore at the Lake Mead reservoir, was presented by the Southern Nevada Water Authority.

The USD447M design/build contract was awarded to Vegas Tunnel Constructors, a joint venture consisting of Lombard, S. A Healy and Impreglio.

The 1500t TBM was shipped from Schwana in Germany to the Port of Long Beach, California, and then transported to the Nevada jobsite by road.

The 9.5m diameter, 190m deep access shaft is equipped with a gantry system with dual 200t winches.

The TBM will begin boring later this month and is expected to meet the project completion date of July 2012.

## Government to invest in Dnieper

UKRAINE

**T**he Ukrainian government plans to construct at least five underground transport tunnels, as well as about 50 subway stations in Kiev as part of a new Kiev General Master Plan, Sergei Bronevitsky, Chief of the Urban Planning, Architecture and Design Department of Kiev government announced.

Bronevitsky said three of the tunnels will be constructed under the Dnieper River, with two other tunnels on the right bank of the same river.

"The new tunnels will help solve

the problem of traffic congestion in the city's downtown. They will also act as transport channels under existing water barriers in the north and south of Kiev," said Bronevitsky.

Bronevitsky said a 7km tunnel under the city centre will be the major project in the list, with the total cost for its construction expected to exceed EUR 350M (USD 298.6M).

This will be a 2-level road tunnel with three lanes in both directions, each one 3.5m high. The estimated construction period is 45 months.

He also said that the

government plans to start construction of two other tunnels on the right bank of the Dnieper River.

In addition, the concept of Kiev General Master Plan involves the construction of about 50 subway stations, an average of three stations per year. Bronevitsky said there is no plan to construct a belt line of the Kiev's metro. Instead, the authorities of Kiev are planning to launch a city commuter train which will connect all the existing metro lines and the city's central railway station.

All the projects are expected to be completed by 2025.

## Henn and Soule release grout book

USA

**R**aymond Henn, a senior consultant, and Nate Soule a senior engineer, both with Lyman Henn, a division of Brierley Associates LLC of Denver, Colorado recently released their book titled 'Ultrafine Cement in Pressure Grouting'.

The book was published by the

American Society of Civil Engineers (ASCE).

The book represents Raymond Henn's third on the subject of grouting, focusing on underground construction.

The first two books are 'Practical Guide to Grouting of Underground Structures' (which has been reprinted and is again available through the ASCE) and

'AJA Guidelines for Backfilling and Contact Grouting of Tunnels and Shafts'. Both of these books were also published by the ASCE.

Released on 28 June, 'Ultrafine Cement in Pressure Grouting' comes in paperback form and contains 94 pages.

Raymond Henn is an adjunct professor of tunnelling at the Colorado School of Mines.

# Finne Tunnel breakthrough

## GERMANY

The second Herrenknecht TBM at the Finne Tunnel in the German state of Saxony-Anhalt broke through last month. Some 200 invited guests were present as the machine entered the reception pit.

The two TBMs broke through four and six months prior to their planned arrivals. This was achieved with peak advance rates of up to 800m of bored tunnel per month.

The two high-speed rail tunnels, 6825m long with a 10.82m diameter, were driven in 19 months (TBM1) and 14 months (TBM2). This included assembly of the slurry shield sections, each taking approximately six months, and the underground conversion of the TBMs.



## News in brief

**India lays foundation**  
Indian National Congress president Sonia Gandhi will lay the foundation stone of the Rohtang Tunnel in Himachal Pradesh's Kullu district on 28 June. The 8.8km horseshoe shaped tunnel, under the Rohtang Pass, will provide all-weather connectivity to the state's Lahaul and Spiti districts. Work on the construction of Rohtang tunnel will be completed by 2015

**Tunnel threatens homes**  
A block of historic homes in Sydney may be demolished for the Australian government to build a AUD 4.53bn (USD 3.8bn) CityRail 'relief line'. RailCorp has confirmed that it has plans, dating back eight years, that would require the acquisition of properties for a 'dive' that would allow trains to enter the new 5km tunnel running from Eveleigh to Wynard.

## Malad tunnel leak plugged

### INDIA

**H**industan Construction Company (HCC) announced last month that it had completed the repair and restoration of the damaged Malad water supply tunnel well

ahead of its scheduled date of completion (T&T, May 2010, p8). With this, the drinking water supply to the western suburbs of Mumbai was restored to normality within a couple of days of completion.

The 12km tunnel was closed

three months ago after water was found leaking from a borehole created accidentally by two men illegally bore well digging. During the repair works, an old pipeline continued to supply water to the region. (See in depth p15).

## Curved micro completion

### USA

**N**ortheast Remsco Construction last month successfully completed a planned, curved microtunnel in Hartford, Connecticut, USA for the Metropolitan District Commission. The tunnel, designed by AECOM, is one of the first curved microtunnels to be constructed in the US. The tunnel is part of the USD1.6 billion Clean Water Project underway in Hartford.

The project includes three basic elements: reduction of combined sewer overflows (CSO's) with the Hartford central sewer system; elimination of sanitary sewer overflows (SSO's) in the sanitary sewers of Wethersfield, West Hartford, Windsor, Rocky Hill and Newington; and nitrogen reduction.

Although much of the project involved trenchless technology this section had originally been planned as trenched. However, the density of other utility services in

the vicinity of this section encouraged contractor Northeast Remsco to suggest the alternative method of microtunnelling for the drive between shafts MHD and MHK. Such was the complexity of obstacles that the precise alignment was modified several times until the most suitable course was finalised.

The machine used for this drive was the Herrenknecht AVND 1800AB MTBM equipped with a SLS Microtunnelling LT guidance system supplied by VMT GmbH.

# Busan-Geoje milestones



## KOREA

The Busan-Geoje Fixed Link project in Korea achieved two major milestones last month. The key segments were placed in both bridges that form major parts of the link, thus completing the main parts of the bridge structures; and the last of the 18 immersed tunnel elements was placed on the seabed and connected to the rest of the elements.

The only remaining gap on the link is the 1.4m closure joint in the immersed tunnel that connects the last element placed with the cut-and-cover structure on the artificial island of Jangjuk. The section is due to be

**Left: The project should be completed on time and opened later this year**

completed this month.

The 3.4km tunnel, which was designed by the joint venture of Danish company Cowi and Korea's Daewoo Engineering and Construction, forms part of the 8.2km highway link project that aims to reduce travel times between Korea's southern coastal city of Busan and the island of Geoje, a major tourism destination and home to some of Korea's biggest shipyards.

The tunnel, which will carry traffic at a depth of up to 48 m below sea level to avoid large container ships, is the deepest concrete immersed tube tunnel in the world. The achievement of these milestones means that all the high risk civil engineering works are now completed on the project and that it will be delivered on time and opened later this year.

## Yangtze tunnel opens

### CHINA

The tunnel running under China's longest river, the Yangtze, in Jiangsu Province opened at the end of last month. The 6-lane project, which includes a 3790m tunnel, took more than four years to build and cost USD 603M.

The project encountered several difficulties in the underwater geological environment, with various technical problems having

to be overcome.

"An area as big as a nail has to bear about 6.5kg of pressure at a depth of 65m. That is a lot of pressure for a tunnel to bear," said the project's chief engineer Han Xiangyang.

The tunnel is the third traffic tunnel built under the Yangtze after the one in Wuhan, and another in Shanghai. It is able to handle double the traffic-flow of the Nanjing Yangtze River Bridge.

## New line in Santiago

### CHILE

Chile's capital Santiago will get an additional metro line, the country's president Michelle Bachelet announced earlier this year. Construction of Metro Line 6, intended to relieve overcrowding on Line 1, is expected to start by the end of this year.

The 14.8km 12-station line will cost around USD 957M and is scheduled

to open at the end of 2014.

Designated 'Linear Expresso Sur' Line 6 will run from Pedro Aguirre Cerda station diagonally through the city centre to Tobalaba station. Metro connections will be provided with Line 1, Line 2 and Line 5, as well as to commuter rail services to Rancagua and San Fernando.

January this year already saw the opening of a 3.8km extension of Line 1.

## Tunnel bosses thank locals

### GREAT BRITAIN

Bosses of the £260M (USD377M) second Tyne Tunnel scheme last month thanked the residents of central Jarrow for their patience. The locals have lived through the disruption of the New Tyne Crossing project for 18 months.

In a joint letter published in the Jarrow Festival brochure, managing director of tunnel concessionaire TT2 Ltd Trevor Jackson and chairman of Tyne and Wear Integrated Transport Authority Councilor David Wood thanked them for putting up with the work.

The statement reads, "We would like to thank the people of Jarrow for their patience as we build the second Tyne vehicle tunnel."

"Over the past 18 months,

central Jarrow has been dug out to a depth of up to 30m (that's the same as six double decker buses) and the new tunnel is almost fully built at the bottom of this deep trench."

"We have now started refilling the space above the tunnel with soil, so that the site will soon be returned to ground level."

"By February 2011 the new tunnel will be open to traffic, at which point the area above the tunnel — the construction site — will be landscaped and the existing vehicle tunnel will close for full refurbishment. We look forward to bringing you all the features of the New Tyne Crossing in December 2011."

The Tyne Tunnel was set to close at the beginning of this month so the original Howard Street Bridge, in Jarrow, could be demolished.

GUANGZHOU | SACRAMENTO | DELHI

# SWIFT EPB.

At 336 m in one month, a Robbins EPB is tunneling the Guangzhou Metro faster than any of the other 60 TBMs on-site. In Sacramento, a Robbins EPB has achieved a rate of 45 m in 24 hours — while installing PVC-lined concrete segments. And in Delhi, a Robbins EPB has advanced a record 202 m in one week—beating the rates of the other 14 machines on the Metro project.

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# EPBM record on Chengdu



Contractors on the Chengdu Metro in China celebrated a citywide excavation record of 457.5m in March. The 6.26m diameter Robbins EPB has excavated at rates of up to 24m per day – faster than any of the 11 other TBMs working on the project.

The machine began excavation of Line 2, Lot 18 of the Chengdu Metro in January 2010, as part of a project for the China Railway Construction Corp (CRCC). By May, the machine had excavated approximately 1000 m of the 2.7km tunnel, to be bored in two sections. Cutter wear was minimal, with no cutters changed since the start of boring.

“These achievements are due to the strong support of field service during assembly, commissioning, maintenance, and excavation,” Li Quanshe of CRCC wrote in a letter to Robbins.

The machine was designed to excavate geology found nowhere

**Left: The 6.26m diameter machine excavated up to 24m per day**

else in China, consisting of highly permeable pebbles and sand, and clay. A mixed ground cutterhead, mounted with 17-in. (432-mm) diameter disc cutters and carbide bits, was manufactured specifically to excavate the geology effectively. A foam injection system stabilises running ground, with each cubic metre of foam mixture able to stabilise about 40 rings of ground. Subsidence is being intensively monitored and crews are trained to utilise probe drilling and ground consolidation if settlement is detected.

China’s Chengdu Metro will open in three stages, with Line 1 operational by 2010. The 26.7km Line 1 will provide service between Honghuayan and Shiji Square stations at speeds of 80 km/h. The 50.6km long Line 2, with 17.6km of tunnels, will include 26 stations between Longquandong and Shiniu areas. Seven lines totaling 274km are planned to be operational by 2035, and will service 13.1M daily passengers.

## BC tunnel fire

CANADA

A fire burning inside a tunnel on the Kettle Valley Railway in British Columbia, Canada was being left to burn itself out at the start of this month as it posed a safety risk to fire crews. The fire in the Adra Tunnel near Naramata was found burning through the timber structure inside.

Authorities decided against extinguishing the blaze over concern for smoke inhalation and the tunnel’s structural instability. The tunnel has previously been condemned and closed to the public due to falling rock and flooding. It is not known how the fire began. British Columbia Wildfire Management said that they would monitor the fire to ensure it didn’t spread.

## LED lit tunnels

NORWAY/NETHERLANDS

Two European tunnels will make the switch over to LED lighting later this month. The Bjorvika Tunnel in Oslo, Norway will use LEDline as a ceiling traffic guidance system, while the Netherlands’ Vlakte Tunnel will be lit by T-Line provided by Indal.

The lights in the Bjorvika Tunnel will be able to sequence along with the traffic, meaning that if there is the need to switch to the other tunnel, the LEDline lights will illustrate this by leading traffic from one tunnel to the next.

The LEDline is mounted into stainless steel supports



on the ceiling of the tunnel in a continuous length.

Each 400mm long unit is remotely, individually computer addressable, so that each can be told to switch on or off for a particular

interval creating any sort of sequencing, flashing / pulsing or dimming action.

**Above: Any sort of directional leading lighting can be created in any direction**



[www.selitunnel.com](http://www.selitunnel.com)

# BORING THROUGH FUTURE

INDIA  
Kishanganga  
Project



SELI

SELI

# Washington sends out RFPs

## TENDER

The state of Washington sent requests for proposals last month to the three teams vying to design and build the 2.7km deep-bore tunnel Alaskan Way Viaduct replacement tunnel.

The state's Department of Transportation (DoT) is looking for a design/build contractor for the USD 2bn project. The sum includes cost of construction,

right-of-way purchase and design. The cost of tunnel boring construction itself is estimated at USD 350M.

The data delivered to the teams vying for the contract was handed over on hard drives.

DoT is seeking proposals from the teams that will include how the TBM would be designed and operated.

The teams will submit their proposals this Autumn. The bid will

be awarded at the start of next year, based on the teams' technical abilities and their bid prices.

The three teams vying for the work are: Seattle Tunneling Group – jv of S.A Healy, FCC Construction, Parsons Transportation Group and Halcrow. AWW – jv of Kiewit Pacific, Bilfinger Berger Ingenieurbau, and AECOM. And Seattle Tunnel Partners – jv of Dragados USA and HNTB Corp.

# Sika takes Dyflex

## ACQUISITION

Switzerland-based construction materials technology company Sika has acquired a majority stake in Japanese company Dyflex. Dyflex is the market leader in liquid waterproofing in Japan with well-established brands and channels. The consolidated net sales in 2009 were approximately JPY14bn (USD153M), with around 350 employees.

Sika can now enter the Japanese construction chemical market. Dyflex's products and technologies will be rolled out to other countries through the global sales network of the Sika Group. Dyflex's customer base and sales channels present significant potential to Sika for cross selling. With the combined product range Sika can offer complete waterproofing systems and solutions to the customers.

# THE contract awarded

## CONTRACT

Skanska has been awarded a design/build contract for a new rail tunnel in New York by client New Jersey Transit.

The contract relates to the Palisades Tunnel, which is part of the new Trans-Hudson Express Project (THE Project), construction of which will double

rail capacity between New Jersey and New York.

US Skanska's share of the contract amount is USD 52M, which will be included in second-quarter order bookings. Skanska has a 20 per cent share of the total contract amount of USD258M.

Palisades Tunnel comprises 1600m-long twin tunnels that will be bored by TBM or open cut. The finished

internal diameter of the tunnels will be 7.2m. A large shaft measuring 36m in diameter and six cross-passages also form part of the project.

Work on the project has begun, and will be completed in December 2013. The other partners in the contract are Schiavone and Shea who have shares of 50 and 30 per cent, respectively.

## News in brief

### ▼ ASTRA Switzerland's plan

The Federal Roads Office of Switzerland ASTRA has developed a EUR 843M (USD 1bn) refurbishment programme for 2012-2016 to cover: signs for delimitation, demarcation and illumination of escape routes and emergency exits; and escape routes in high and low density traffic tunnels throughout Switzerland

### ▼ Fuerstenfelder contract

The joint venture of Dr. Alfred Zettler & Ertl; and Horn & Partner secured the EUR199 900 (USD241 271) contract for project management, planning and coordination during construction of the Fuerstenfelder expressway S7 west section in Germany

# Akkerman signs agreements

## PARTNERSHIP

Akkerman set itself up for sales in new markets by recently establishing representation in India, Singapore, Russia and the Middle East. The company signed agreements with the UAE's Trenchers Land Digging and Filling, India's Asia Contech, Intertorg of Russia, and ICE Far East based in Singapore.

Trenchers Land Digging and

Filling, based in Dubai, recently facilitated the sale of a complete GBM system for a Kuwaiti contractor. The sale represented the first GBM system sold anywhere in the Middle East. The 4812A jacking frame has 200t of thrust, a 275T power pack, a powered cutterhead and a jetting and lubrication pump to install DN 300-1000 pipes for drives up to 150m long.

Intertorg of Moscow is a US-based company that specialises in

the Russian trenchless market and has been a long time dealer for Ditch Witch, having previously represented Lovat, Soltau and MTS Equipment.

Asia Contech of New Delhi will provide sales and service of Akkerman equipment in India. The company also represents trenchless companies American Augers, ASTEC and Trenchor.

ICE Far East will represent Akkerman in Southeast Asia.

# Ex-Halcrow boss joins MTR

## PEOPLE MOVES

Former Halcrow director of major projects Alan Myers last month became chief civil construction engineer for Hong

Kong's MTR Projects Division. Myers' job will be to provide a general overview and independent perspective of the USD23bn rail expansion plans. Myers worked as the tunnelling

director of Balfour Beatty, as well as his role at Halcrow, and brings a wealth of experience to the job.

In 2009 Myers was inducted into the Construction Industry Awards 'Hall of Fame.'

# Dartford safety upgrade

## CONTRACT

Highway chiefs will inject more than GBP 8M (USD 11.6M) into the Dartford Crossing to improve its safety. The money will be used for a sprinkler system in both tunnels, designed to keep a fire under control during the wait for the emergency services to arrive.

The upgrade was awarded to tunnel safety specialists Fogtec Brandschutz. It is estimated to cost

GBP 8.1M (USD 11.8M), will start in October this year and is due to finish in 2012. It will be similar to fire detection systems installed in the Channel Tunnel following a large blaze there in September 2008.

Project manager for the Highways Agency Paul Harding said, "Fortunately, fires in tunnels are very rare, but improved safety in the Dartford River Crossing tunnels, along with all our road, remains a priority."

"The Dartford tunnels are

currently safe, and the fire suppression system will provide even greater protection for road users, our maintenance staff and emergency service staff should a fire occur," Harding continued.

The improvements were prompted by an EU tunnel safety directive brought in following the deaths of 39 people in France's Mont Blanc Tunnel in 1999, as well as a blaze in a funicular train tunnel in the Austrian ski resort of Kaprun in 2000 which killed 155 people.

## News in brief

**Benesch & HWS team up**  
Engineering firm Alfred Benesch & Company announced last month that the company will merge with HWS Consulting Group based in Lincoln, Nebraska. The combined firm will have approximately 370 employees and will practice as Alfred Benesch & Company.

**Nora Lanken contract**  
Bravida Sverige of Stockholm secured the turnkey contract NL 67 for design, supply, installation, testing and implementation of ventilation tunnels on Norra Lanken, Stockholm's north ring road at the end of last month.

**Svegatjorn-Radal contract**  
Vestnorsk brunnboring secured the EUR484 600 (USD591 600) contract for installation of water wells and monitoring regimes along the line of E39 Svegatjorn-Radal, where several long tunnels are to be built. Water quality and fluctuations are to be measured before and throughout the construction period from 2011-2014.

**New BTS member**  
British stainless steel fabrications company Ancon has joined the British Tunnelling Society.

# Madrid to host Expomatec

## CONFERENCE

Madrid will host the first of a series of triennial business conferences and exhibitions next May, it was announced last month. Expomatec, which will run from 17-20 May at Ifema, is being organised by Ifema and Grupo TPI.

The conference will facilitate the meeting of construction industry professionals and delegates from the countries with large infrastructure budgets, including those of South America, Eastern Europe and North Africa.

The conference will cover infrastructure, civil works and

mining. Ifema is a large venue that includes an underground station, auditoria for up to 1500 people, almost 100 meeting rooms, parking for 14 000 cars, as well as access to 55 000 hotel rooms in Spain's capital city. The facilities are two metro stops away from Barajas airport.

# Eurotunnel snaps up firm

## ACQUISITION

Channel Tunnel operator Eurotunnel last month bought Great Britain's third biggest rail freight company in a GBP31M (USD45.2M) deal. Eurotunnel's purchase of GB

Railfreight is part of the company's plans to increase rail freight through the Channel Tunnel after it went down during the recession.

GB Railfreight, which has been owned by transport company Firstgroup since 2003, is the

second major British rail company to change hands over the past few years after EWS was bought out by Germany's Deutsche Bahn in 2007. The deal represents a "further expression of our commitment to the UK," said Eurotunnel chairman Jacques Gounon.

# Hong Kong tenders invited

## TENDER

The Hong Kong Highways Department (HyD) invited tenders last month for the Central-Wan Chai Bypass Tunnel and Island Eastern Corridor Link contract. The works are expected to begin in September for completion in 2017. The works mainly comprise construction of a 300m section of tunnel in North Point at the East Portal;

construction of an approach road to the tunnel; modification of Island Eastern Corridor between Hing Fat Street and Po Leung Kuk Yu Lee Mo Fan Memorial School; modification of Victoria Park Road and Hing Fat Street junction, and adjacent roadworks; construction of sub-structures for the Administration Building and East Ventilation Building; demolition of Rumsey Street Flyover eastbound down ramp in Central; and

associated works including landscaped deck, noise barriers, noise semi-enclosures, road drainage and landscaping works.

The Major Works Project Management Office of the HyD has appointed AECOM Asia to design and supervise the construction works.

Interested contractors may obtain the tender forms and other particulars from AECOM Asia Company Limited on 12th floor,

Grand Central Plaza, Tower 2, 138 Sha Tin Rural Committee Road, Sha Tin, New Territories, Hong Kong.

Tender submissions should be placed in the Government Secretariat Tender Box located at the lift lobby on the lower ground floor of Central Government Offices (East Wing), 20 Lower Albert Road, Hong Kong. Submission of tenders will close at noon on July 30, 2010 (Friday).



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# Filling the gap

## MALAD TUNNEL

Last month's announcement from Hindustan Construction Company (HCC) that it had completed repair and restoration works on the damaged Malad water supply tunnel in Mumbai brought to a close a saga that ran from February. The 12.5km tunnel was ruptured after two men, the plot owner and the contractor, damaged the main pipeline while drilling an illegal bore-well into it.

After causing the burst both men attempted to seal the crack but failed to stop the tunnel from leaking out. As soon as the leak was discovered, authorities temporarily resolved the problem by inserting a wooden plug, but repair work was needed urgently to stop the crisis becoming greater. There were worries that the leaked water could weaken the foundations of nearby buildings.

The tunnel was leaking approximately five million litres of water a day until April when HCC quoted an estimated INR 5

crore (USD 1.1M) for the final repair work. HCC and the Municipal Cooperation of Greater Mumbai (MCGM) then contacted Belgian company de Neef Conchem (DNC), specialists in preventative and remedial waterproofing, to find a solution for sealing the leakage in the tunnel. DNC's technical department then studied site conditions before preparing a method statement for sealing and repairing the tunnel.

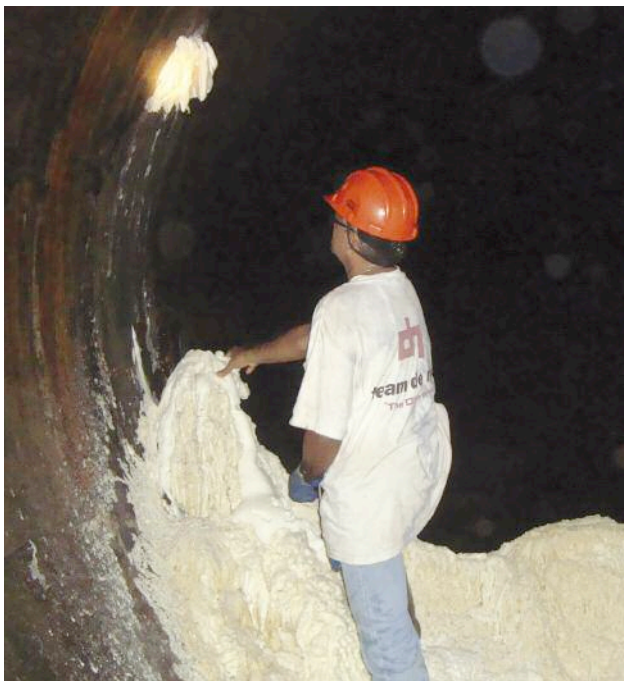
DNC's technical support manager Peter Zanders explained to T&TI the procedures taken to repair the leak. Injection was executed in co-operation with Kasturi Projects India. Inspection, calculation and injection took place on 7-9 May.

First, a CCTV camera was lowered into the borehole to investigate the situation down to a depth of 70m. The images from the camera determined the final combination of techniques to be used.

A 2-component polyurethane – Rockstab WX – was injected through a specially adapted inflatable packer to seal and



**Top:** Tunnel damage repair included a stainless-steel plate  
**Above:** Preparing to inject 2-part PU grout into the borehole  
**Bottom left:** The borehole grout reached the tunnel



consolidate the bottom part of the borehole next to the tunnel.

After the Rockstab WX injection, the CCTV camera was again lowered into the borehole and the images revealed that the borehole was now sufficiently sealed.

The second injection was then made with a one-component polyurethane – HA Cut with 10 per cent catalyst HA Cut Cat F (fast catalyst) – also using an inflatable packer adjusted for the job. This injection sealed all remaining fine cracks in the rock and the tunnel crown.

The third injection step was a 'Combi grouting technique' where, after the installation of a single inflatable packer, first a fixed amount of one-component polyurethane – HA

Cut with 0.5 per cent HA Cut Cat AF (normal catalyst) – was injected, immediately followed by a pressurised cement grout. The remaining length of the borehole was then filled with a non-shrinking cement grout and sealed off with concrete near ground level.

When the dewatering of the tunnel was completed and the tunnel cleared for access, the injection work was inspected from the inside of the tunnel where it was clear to see that all leakages were sufficiently sealed and consolidated.

The damaged part of the tunnel wall was repaired and a stainless-steel plate was installed as additional reinforcement.

**Kris Mole**



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GRANDS PROJETS

# Back to school

I've just finished my first year back in the classroom again after 15 years of administration roles in both the U.S. federal government and academia. Returning to the classroom has been hard but exciting. However, I will admit to being disheartened to find that the problems faced by the underground construction profession and industry in the U.S. have only become more serious with time, and the subjects at issue are the same as they were 15 years ago.

We still don't have education programmes in the United States that produce the technological and business leadership that the tunnelling and underground construction industry needs for a healthy future. But I know that academe can respond effectively if owners and industry leaders can come together and tell us what you need and what you can support.

Our industry has to underpin the future of the sustainable world, particularly as it relates to the mega cities and the critical issues of energy and water. Infrastructure investments will be huge, and our industry needs to be prepared to provide quality and sustainable service provision that the world needs. If we plan now, and well, we will be the resource that is needed to address both small and local problems and also complex and large-scale problems, which engage integrated planning and social equity issues. To do this we need to mould engineers who are entrepreneurial and savvy in the ways of multi-cultural business, and who have global perspectives and interest in sustainability. In the future, the engineering profession should be known for leadership, not commoditised technology expertise.

Here's one way to do that. Let's build an executive management degree for underground construction. Structured similarly to an executive MBA (master of business administration), it would not be a research degree, nor would it be predominantly focused

on business, management or engineering. This degree could incorporate technology, finance, policy and planning issues, sustainability, disaster response and more. As most people in the engineering world already have a master's degree, this could be an executive doctorate of the profession (e.g., engineering, construction), which wouldn't be confused with the more business management-centred MBA.

Take for example the Doctorate in Economics in International Business from the Stockholm School of Economics in Sweden. Launched in 1976, this programme was heavily endowed by the owners of major Swedish companies. Its objective was to prepare students for a very different business world beginning to emerge where natural resources were limited, customers had global perspectives, and mass production tied to mass marketing was no longer key to growth. Graduates of this programme went on to become CEOs of major international firms, developed new companies or became professors at noted universities. Its graduates were seen as the most advanced researchers in the field of international business.

Aim an executive level degree in underground construction at engineers who've spent several years in a management position, and have experience resolving challenges inherent in the tradition of engineering practice. Include upper level engineers who are looking to move into international leadership roles, and who are ready to tackle the bigger issues that the peoples of the world are facing.

By nature, people who want to solve and simplify problems often self-select to study engineering. But engineering in the future is a profession that must engage the more complex problems. This programme would invite other kinds of people into engineering, and develop those individuals into leaders with the necessary skills to manage future corporate



challenges. It would train high-level engineers, planners, technologists and scientists to hold positions of responsibility in production, research and development and management. Participants would gain the global competence and business acumen needed to compete at home and abroad, and so would the industry. We need to approach the bigger, world issues in a more integrated and holistic fashion. We need a place for these individuals to come together and think about the finance, about service provision, risk and resilience, technology, the information systems and the cultural aspects.

Key characteristics of the programme would include cohort operation where participants could enrich one another by sharing their diverse professional, cultural, educational perspectives. They would have the opportunity to discuss the most current strategic and operational issues of international business with guest seminars by prominent business

leaders. Interaction with globally experience CEOs and senior executives in the classroom and on projects would be an integral part of the learning concept.

With a programme like this, the underground construction industry could provide the people we need to plan our future. If it doesn't come out of our industry it will come out of another industry and we will once again be in the back seat. It's time for us to be in the front seat and leading the sustainability questions and answers for the future. It is not acceptable for us to stand still. I'm ready to work very hard to deliver an excellent education programme for the industry. Tell me how I can help you. Let's not be discussing the same problems 10 years from now. Let's be gauging our progress.

**Dr. Priscilla Nelson,** professor of civil and environmental engineering at the New Jersey Institute of Technology, was interviewed by staff writer Nicole Robinson.



## One for two.

**Herrengrosserstedt/Germany.** As specialist in conveyor belt systems, H+E Logistik GmbH supplied the equipment required for the new construction of 2 tunnel tubes with a length of 7,000m each, which will accommodate a high speed train on the German railway route from Erfurt to Leipzig/Halle. This equipment guaranteed rapid tunnelling progress. The system includes two continuously extendable tunnel belts which are connected to a heap belt and operate a pivoting stacking system. This saves costs and maintenance work. Typical H+E.

### The bare facts:

- Tunnel diameter: 10.90m
- Conveyor length: 2x 7,000m
- Belt width: 1,000mm
- Capacity: 2x 1,400t/h
- Installed power: 3x 250kW per tunnel
- Belt storage capacity: 2x 500m/horizontal
- TBM: 2x Hard Rock Shield
- Installation: 2008
- Contractor: JV Finnetunnel



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# Donald Frank Rees

It is with sadness that we must report the death of Donald Rees OBE, who recently died in the Algarve at the age of 91. He was a much-acclaimed engineer and businessman and pioneer of the No-Dig (trenchless) industry. Ironically, many of his innovative engineering achievements remained hidden. Donald played a very active role in the early days of *T&T* as Editorial Advisory Board Chairman for the *BTS* in the late 1970's and early 1980s.

Born in South Wales, Donald was the youngest of three children. His father was an ambitious Cockney with a great sense of fun. His Scottish mother was warm and easy-going, a balancing force. Donald inherited all these characteristics.

Growing up in Cheltenham and London, he exuded enthusiasm despite the aftermath effects of the First World War, the hardships of the Great Depression and the approach of World War II. He revelled in the advent of domestic electricity, wind-up phones, Al Jolson on the wireless and dancing the night away to big bands in the Hammersmith Palais.

A mischievous student at Cheltenham College, he had hopes of studying engineering at Cambridge University. At his father's suggestion, he opted instead for the 'University of Life', a decision he never regretted.

On returning home from WWII, he found that his father's road surfacing company had been decimated by wartime exhaustion and austerity. With typical forward-looking boldness, he took on the challenge of reinvigorating and modernising the business.

On first encountering Mary Smith, an 'utterly gorgeous' nurse working in the General Hospital in Brighton, "I could not resist approaching her and inviting her to have tea with me," he recorded in his diaries. "She said she would be delighted." They married in 1947 and moved to their first 'dream house' in Horley, Surrey.

Donald and Mary had six sons.. The main family home for most of their time in England stood next to the 18th tee of one of the world's most celebrated golf venues, the West Course at Wentworth.

Meanwhile, Donald was greatly expanding his father's business by undertaking public works underground as well as at street level. Under his guidance, the company developed innovative methods of restoring old, and in some cases bomb-damaged, sewage systems. The traditional repair techniques involved

roads being dug up, causing delay and disruption, but Donald and his colleagues developed 'No-Dig' tunnelling techniques based on the Rees Mini-Tunnel; they also pioneered the use of close circuit television cameras in subterranean investigations.

Commenting on the news of Donald's passing, Dec Downey, current chairman of the International Society for Trenchless Technology (ISTT) said, "Donald opened the first No Dig Conference in London in 1985 posing the question 'Is there a NoDig future?' Along with other founders of ISTT he worked to establish that future; he helped organise the 1987 Conference and served as an ISTT Guarantor for almost 20 years, submitting thought-provoking contributions long after retiring to Portugal. His contributions to pipeline investigation and pipeline construction were also significant. He is remembered by pipe jacking and tunnelling pioneer James Thomson who shared the platform with him in 1985 as a tough competitor and a visionary innovator; they shared knowledge of many successes and failures and became firm friends in the process, exemplars of the ethos of UKSTT and ISTT."

Looking at Donald's contribution to the inception of the 'trenchless' industry, Ted Flaxman, founding chairman of ISTT, said, "I first met Donald Rees many years ago in connection with a job in King's Lynn where some particularly challenging deep construction near the ancient Custom House involved the use of his firm's Mini-Tunnel, an innovative technique for small size tunnelling. We were delighted when he agreed in 1980 to join the small 'Working Party on Trenchless Construction' which was being formed by the Institution of Public Health Engineers. His contributions to the deliberations of that body were lively and constructive and occasionally hilarious. After the Working Party had reported to the Institution it was decided to initiate in 1985 'An International Conference and Exhibition on Trenchless Construction for Utilities' in London. At several meetings we wrestled with the problem of coining a shorter, snappier, title for the event and it was Donald Rees and James Wishart together who eventually came up with the 'No-Dig' title which has continued in use by the industry ever since."

Donald made a major contribution to that first, very successful, No-Dig Conference in 1985 and he later took an important part in the follow-up which resulted in the



formation of ISTT in 1986.

Ted went on to say, "Donald's irrepressible character was well and truly illustrated two years ago when he reached the grand old age of 90. Joan (Mrs Flaxman) and I had never actually visited his home in Portugal, despite repeated invitations, but he sent us a very professional DVD recording the three happy parties which took place on separate days to celebrate the occasion. On the actual date of his birthday we sent him an email of hearty congratulations. The reply we received showed that, despite the advancing years and the loss of Mary, he had not lost any of his zest for life. Donald was a splendid character who will be long remembered for his innovative thinking and warm friendliness."

As a liveryman and later Master of the Worshipful Company of Paviers, a Fellow of the Institution of Public Health Engineers and a Companion of the Institution of Civil Engineers, Donald was adept at cultivating business contacts and marketing. In addition to an impressive array of industrial awards, including Design Council Awards for the Mini-Tunnel and CCTV Camera System, and the Queen's Award for Industry, he was honoured with an OBE for his services to British exports.

Attracted by its mild climate, Donald and Mary built a charming house in the Algarve, near Porches, for their retirement in 1983, where Donald was to become a keen participant in the fledgling AFPOP (Association of Foreign Property-Owners of Portugal). After 55 years of marriage, Mary died in Portugal in 2002. She had been Donald's constant inspiration, and he often told friends, "not a day goes by in which I do not feel her loss sorely."

After a short period of poor health and with family at his bedside, Donald died at home near Algoz, in the early hours of 18th April 2010, the day before his 63rd wedding anniversary. He will be sorely missed by his six sons and their families, including 11 grandchildren and 3 great grandchildren. ■



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# Ross McKenzie

Ross McKenzie started his career in academia but ended up in tunnelling and contracting almost by accident. He was carrying out some studies for Taylor Woodrow in connection with a tunnelling project and got bitten by the tunnelling bug.

He joined the Taylor Woodrow tunnelling section headed by Colin McKillop and gradually rose to be Director in charge of tunnelling projects in Taylor Woodrow Civil Engineering. He was particularly involved in outfall tunnels for power stations and in his early years he was involved in Fawley, Wylfa, Sizewell and Seaton Carew.

I first met him in 1970 at Hartlepool or Seaton Carew as the station is now called. His team was doing the outfall tunnel and I was about to sink my first big shaft. We really started working together in 1982 on the Piccadilly Line Extension to Heathrow Terminal 4 for London Underground and this was quickly followed by the Channel Tunnel on which we started working in 1984.

I can remember Ross ringing me in my car just before Christmas in 1984 to tell me that it looked as though this time the channel tunnel was going to happen. In 1985 the Channel Tunnel Group (CTG) was formed to bid for the concession to build and operate the tunnel. Ross led the construction planning and pricing that went forward to form the successful CTG bid.

He went on to join the newly formed Transmanche Link (TML) who were the channel tunnel constructors and did all the early planning and procurement of plant and equipment as the project got underway. This included, (for the tunnellers), the introduction of the NATM (little used in the UK prior to this) to achieve the underground development at Shakespeare

Cliff. As the organisation expanded Ross took over the responsibility of all engineering for the construction team and remained in that position until the main tunnelling work was completed in 1990.

He returned to Taylor Woodrow and was appointed Director in Charge of tunnelling projects. He got the TW Precast Linings business started and also became responsible for Taylor Woodrow Foundation Engineering. He followed with tunnelling projects such as the Brighton Storm Water Tunnel, the A27 Southwick Hill Tunnel and the Jubilee Line Extension-London Bridge Station.

Ross always tried to introduce innovation into what we did. I think he put the first Dosco in a shield, he always wanted unreinforced linings, he used Hagglund cars as bunkers in the pit bottom to turn round trains quickly and achieve record outputs at Heathrow.

With his Foundation Engineering hat on, he became involved in the STAR Rapid Transit system that Taylor Woodrow was constructing in Kuala Lumpur and commuted on a fairly regular basis to and from Malaysia.

He retired in 1997. Having spent many years commuting between London and Glasgow he was keen to get off aeroplanes and into boats and so bought himself a comfortable well powered boat to do some pottering around the Scottish islands.

But of Ross Mackenzie the man, I remember that he constantly spoke of his love for Scotland and its ways, and would often quote a Scottish expression to encapsulate what he wanted to convey.

He was a great thinker and paid huge attention to detail. He would sketch quite intricate little details on the back of an envelope or on a napkin and hand it to one



of the engineers to draw up when he came into the office. He actually had a love of algebra and really enjoyed calculating the angles and the algebraic functions to examine how tolerances might interact, for example, much to the chagrin of some of the consulting engineers.

He was a man of standards and firm opinions who could come across as stern, but was actually a very sympathetic man who always cared for his staff and could see things from their point of view.

He did have a way with words and had a knack of finding the right balance in expressing things particularly to our clients. One expression I remember was his requirement for "a robust solution which erred on the side of optimism" when he was putting together a tender.

He had no truck with bureaucracy or politics and despised "the armchair warriors" as he called them, waving his arm in the direction of the main office, who wanted to tie his work up in red tape. But was always reasonable and professional and is remembered with affection by his team.

Ross was one of the principal tunnellers of his time and we will remember his contribution to tunnelling and to his team.

**Bob Ibell, BTS chairman**

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1



2

- 1 External belt at the Bibra tunnel.
- 2 Stacker conveyor mounted on tripper.

## Efficient conveyor belts for long railway tunnels

The excavated waste material – approx. 1,100,000 m<sup>3</sup> – of the 2 x 6,466 m Bibra rail tunnel on the Erfurt-Leipzig/Halle section of the Nuremberg-Berlin high-speed line is removed from the tunnel by Marti Technik's conveyor belts and then transported beyond the tunnel entrances to the dump storage area. The conveyors have capacity for 500 tonnes/hour.

The three conveying systems are composed of a total of eight belt units:

- System 1, east portal consists of 355 kW conveyors in tunnel, 110 kW link conveyor, 45 kW dump site conveyors including tripper, ended by a 11 kW reversible stacker conveyor.
- System 2, west portal includes 250 kW conveyors in tunnel, 45 kW dump site conveyors including tripper, ended by a 11 kW stacker conveyor.
- System 3 adit window consists of 250 kW conveyors in tunnel and 110 kW link conveyor.

The total installed power is approx 1,000 kW. The belt widths equal 800 mm and 1,000 mm.

The tunnel conveyor is suspended to the tunnel vault by chains on two sides. The tunnel conveyors are fed by crushers in the tunnel. The conveyor is extended by jump of 450 metres to each connection tunnels.

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# Growth potential

Australia's tunnelling industry is enjoying a boom and a series of major upcoming transport projects are set to provide a further boost to the sector. Bernadette Redfern reports

**F**rom Victoria's desalination project to Brisbane's airport road link, a range of mega-projects in Australia are keeping the tunnelling sector buoyant. Further projects such as Brisbane's Cross River Rail Link, Melbourne's West Link highway and Perth Metro are also on the horizon leading to optimism within the sector. As a result both local and international contractors are investing in their tunnelling operations with several firms establishing dedicated tunnelling divisions.

The only shadow on the horizon is that of political uncertainty. After the late stage cancellation of Sydney's AUD 5bn (USD 4.4bn) metro early in 2010, there is understandably an air of caution among contractors and tunnelling firms. This, coupled with the financial failure of several public private partnership projects, means that contractors are being cautious when it comes to analysing project risk and clients are abandoning PPPs and reverting back to traditional financing methods.

In February the Government of New South Wales cancelled the Sydney Metro project after spending almost AUD 300M (USD 263M) on feasibility work and land acquisition. The first phase of the light rail link was a 7km route through the central business district (CBD) and contractors were expecting to use two EPBMs for the main bore and roadheaders for the stations.

But this was not to be and the industry is still reeling from the cancellation. Firms reacted angrily to the news of its demise with bidders demanding compensation for their extensive bid costs. "This project has been on and off for a long time due to the financial state of NSW Government," explains Australasian Tunnelling Society (ATS) member and journal editor David Lees. "The sector has to some degree come to terms with this although the bidders are claiming compensation and the NSW government are under extreme pressure to explain to taxpayers how it soaked up AUD 500M (USD 414) of public

**Right:** Brisbane is a hub of tunnelling activity in Australia

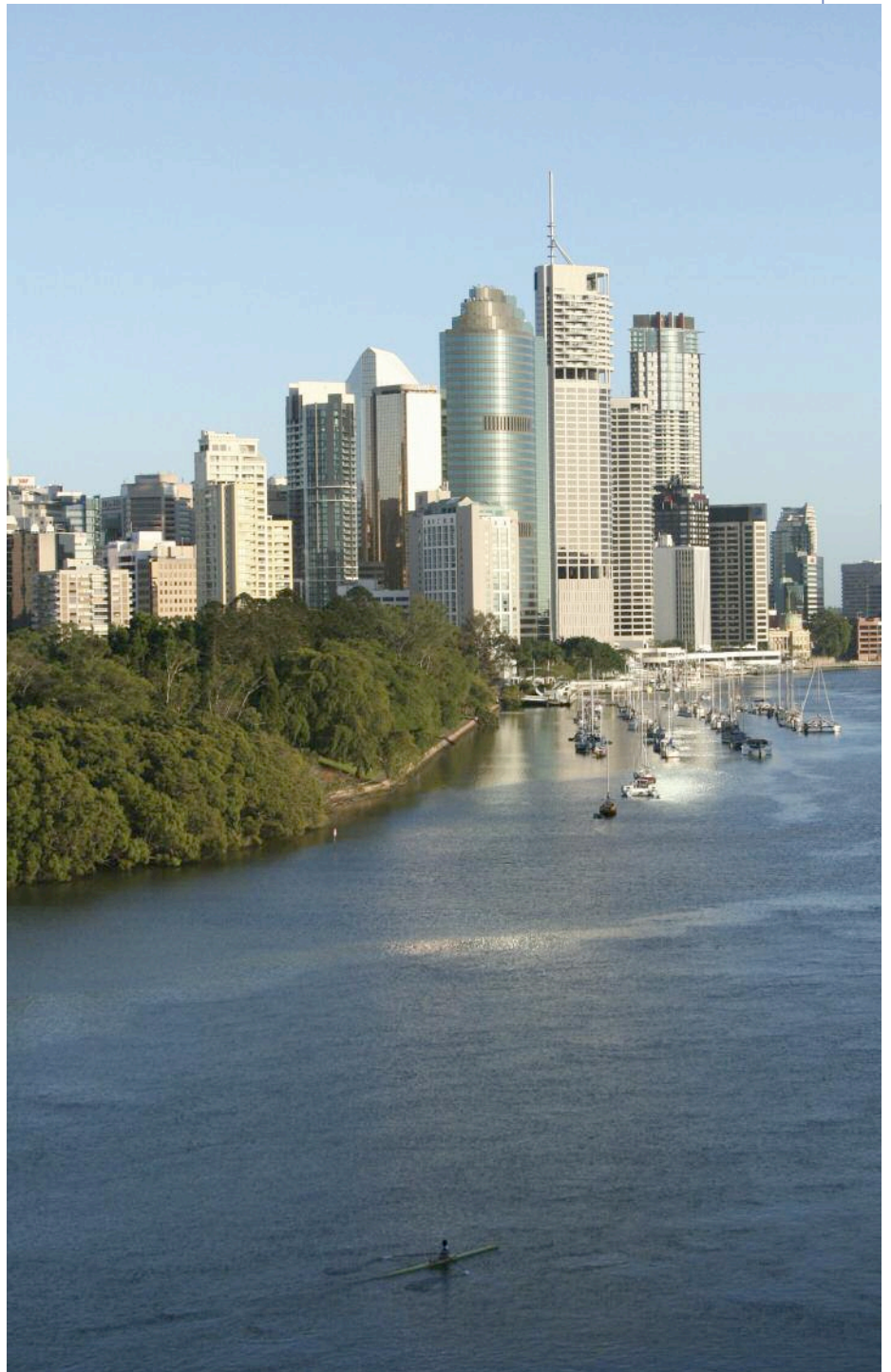




Table 1 - Major projects

Project	Description	Value (AUD bn)	Client	Status
Cross River Rail Link	City rail crossing passing under river, route tbc	8	Queensland Government	Feasibility study underway
Brisbane Airport Link		4.1	Queensland Government	Under construction
Adelaide Desalination Project		1.83	SA Water	Phase 1 due for completion Dec 2010
Brisbane Northern Link	4.5km road tunnel	1.3	Queensland Government	Three bidders shortlisted
Northern Sewerage Project		0.65	Melbourne Water	Construction due to finish mid-2012

money on the shelved project.”

The government has confirmed that AUD 300M (USD 249M) has been spent on the scheme prior to its cancellation, but the bidders, which included a John Holland Tunnelling/Theiss joint venture, are also pursuing compensation for their wasted efforts. This could cost as much as AUD 200M (USD 175M) “It was due to be awarded sometime this month (April) so it was cancelled fairly late in the piece,” says Russell Cuttler, executive general manager specialist businesses at contractor John Holland. “Certainly there are discussions underway over compensation of cost, but we prefer that projects proceed.”

With only two months between expected award date and project cancellation contractors are understandably frustrated at the last minute decision: “Cancelling a project at such a late stage makes it very difficult to manage your people. We have staff all over the country that we want to retain and invest in and it makes that difficult when at the last minute projects are cancelled,” says Rob Muley, general manager for tunnelling at John Holland.

Obviously the cancellation of Sydney’s metro has led to uncertainty over the future of planned projects but contractors are optimistic that schemes will go ahead eventually. David Lees says that the axing of the Sydney scheme is due to local political issues that should not affect other projects. “The cancellation of the CBD Metro reflects the turmoil and political infighting within the current state government of New South Wales and their inability to agree internally on a scheme for the future development of Sydney’s rail network. It has had no impact whatsoever on other proposed underground rail projects in Melbourne, Brisbane and Perth.”

Contractors also remain upbeat. “There is some nervousness about whether some projects will proceed but in the long term we know they will because they are definitely needed,” says Cuttler who is positioning John Holland to make the most of upcoming opportunities. The local contractor is a AUD 3.7bn (USD 3.4bn)

revenue company, owned by construction giant Leighton Holdings. Its specialist tunnelling division is the country’s largest and reported revenues of AUD 422M (USD 393M) in 2009 accounting for 11 per cent of total revenue. “There are only really about half a dozen companies that venture into tunnelling in Australia but we are finding that other contractors are setting up specialist businesses,” he says.

The reason for the focus on tunnelling can be attributed to the massive projects underway and those on the drawing board. The largest scheme on site is the AUD 4.1bn (USD 3.6bn) Brisbane Airport Link in Queensland. Two 12.5m diameter Herrenknecht EPB machines will this summer be launched into soft rock turning it into a 6.7km twin bore road tunnel. “At 12.5m they are the largest TBMs to be assembled in Australia,” says Muley. “It is unusual to use these on a road project but the ground conditions and programme constraints demand it.”

The firm is working in joint venture with sister company Theiss to design, construct and commission the scheme, which is being constructed under a public private partnership (PPP) arrangement by the BrisConnections consortium.

The Airport Link is one of four major schemes that are designed to ease traffic congestion in Brisbane. Two other schemes, the CLEM 7 tunnel opened earlier this year and the 300m Go Between Bridge (named after a local band) over the Brisbane River, is almost complete. The fourth, the 5km Northern Link is currently out to tender. This new tunnel will connect the Western Freeway at Toowong with the Inner City Bypass at Kelvin Grove and is expected to carry 34,200 vehicles per day when it opens in 2014. Three bidders have been shortlisted for the scheme and will submit their final tenders in May. The consortia include Northern Direct, Transcity and the Leighton Baulderstone Razel Joint Venture.

The original completion date was 2016 but the State Government has made a number of changes to the project and accelerated the construction programme.

The most significant change was the decision to axe the envisaged PPP structure and opt for a more traditional funding route. Lessons from previous failed PPPs told the government it would have to guarantee traffic flows to attract private finance, leaving the state with too much risk to make the PPP structure financially viable.

That private sector finance was difficult to find is not surprising given the recent history of PPPs in Australia. Several tunnelling schemes have experienced financial collapse as traffic numbers have failed to deliver the toll revenues that concessionaires were expecting. Most recently Sydney’s 3.6km Lane Cove Tunnel went into receivership with analysts estimating that the AUS \$1.6bn (\$1.4bn) project is now worth just AUD 400M – 600M (USD 350M – 525M). Traffic numbers have so far fallen way short of the 100,000 vehicles per day that were expected to use the route by September 2008 with a high of 62,500 being recorded to date. Other PPPs that have failed to deliver expected returns include Sydney’s AUD 680M (USD 595M) Cross City Tunnel and the AUD 700M (USD 613M) Sydney Airport Rail Link.

Back in Brisbane the emphasis on road tunnels is about to move towards the rail sector as the city plans the AUD 8bn (USD 7bn) Cross River Rail Link project which runs North to South under the Brisbane River. A metro is also at planning stage.

Beyond Brisbane contractors have been kept busy on a range of water related tunnelling projects. “We are working on two sewer augmentation and replacement projects in Melbourne that between them are worth about AUD 1bn (USD 830M),” says Cuttler.

These two sewer projects are the Northern Sewerage Project, consisting of 13km of new sewers built in two phases (see feature page 27); and the 2.2km Melbourne Main Sewer Replacement scheme. Both of these are using EPBMs and in the case of the main sewer replacement pipe jacking and sheet pile coffer dams are also in use.

Other schemes underway with tunnelling



elements include the AUD 1.7bn (USD 1.5bn) Adelaide desalination project and the AUD 5.7bn (USD 5bn) Victoria desalination project. “In recent times there has been a big wave of water projects and now that is changing to transport. Looking forward it seems that everybody is interested in building a metro,” says Cuttler. Lees agrees that the emphasis has changed. “Now the emphasis seems to be on underground metros,” he says.

Historically road projects dominated underground construction and roadheaders were the mechanism of choice when it came to excavation. But over the past decade water projects have taken centre stage bringing more sophisticated boring methods with them. Looking ahead this trend continues to play out as transport schemes and larger diameter bores, dominate future plans. For example the forthcoming west link road in Melbourne,

**Above:** Melbourne is home to several major sewer development projects currently under construction

which will improve traffic flow through the city and to the port, expected to require two 15m diameter TBMs, setting a new record for tunnel bores in Australia.

“The increasing needs of our population, particularly in urban environments, has meant that the Australasian tunnelling industry has kept busy through the recession and is set to surge ahead in years to come,” says Lees.

This future surge is the subject of great excitement among contractors, although they are also cautious about the impact that major projects can have on resources. “Australia is probably heading into another resource boom,” says Cuttler. “Historically the tunnelling market was small by international standards but the last 5-10 years has been a purple patch with lots of progress. We have had to develop a large workforce to meet that demand and that is going to continue and that is one of the big challenges.”

**Table 2 - Construction investment to 2018**

**Construction investment to 2018**

Annual spend forecast by sector (AUDbn)

Sector	Units	2008-09	2009-10	2010-11
Roads	AUD million	16,282	15,627	15,080
Bridges railways harbours	AUD million	6,570	6,326	6,713
Electricity pipelines	AUD million	12,409	12,973	12,777
Water and sewerage	AUD million	7,577	8,454	7,732
Recreation and other	AUD million	3,646	3,302	3,082
Total	AUD million	46,484	46,682	45,385

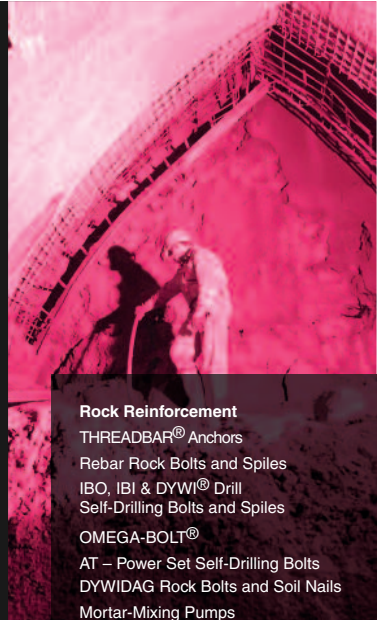
Source: Construction Forecasting Council 2010

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# Managing Melbourne's waste

Complex soft ground conditions, a river crossing and a multitude of existing utilities are just some of the challenges on the Melbourne main sewer replacement project reports Bernadette Redfern

Technology may have moved on since Melbourne's original main sewer was placed in the late 1800s but some things, such as the challenging soft ground conditions, remain the same. So the contractors currently replacing 2.3km of the sewer with a new 1.8m internal diameter glass fibre reinforced plastic pipe are facing some of the same issues that tunnellers first encountered 120 years ago. "Coode Island Silt is a very, very soft silty clay and the original sewer has actually got backflows where the TBM they originally drove sunk," explains Nick Lewis, project manager for Melbourne Main Sewer Replacement (MMSR) project, from contractor John Holland Tunnelling.

Coode Island silt hasn't been tunnelled since the original construction of the Melbourne sewer network but it is well known in the city for being a poor construction material having caused a multitude of difficulties for foundation contractors in the past. But for John Holland Tunnelling and client Melbourne Water, it is a case of so far so good after undertaking approximately 1km of tunnelling using a manned 3m diameter, AUD 5M (USD4.2M) Lovat earth-pressure-balance shield machine (EPBM).

## Melbourne sewer challenge

The MMSR is one of three major projects that John Holland is undertaking as part of a six-year term agreement with Melbourne Water, signed in 2004. The other two are stages 1 and 2 of the Melbourne Northern Sewer Project, which will see 13km of new sewers placed in the city. Each of the three projects have been let individually but overarching these is the term framework. "Each individual contract has been

specifically modified," says Rob Muley, general manager tunnelling at John Holland.

The structure of the MMSR contract is a cost reimbursable performance incentive agreement based on the AS2124 form of contract, where the team are incentivised to work towards a target cost and target timescales for both individual activities and the entire programme. There are also safety and environmental objectives to meet. "If we achieve all of our criteria then these [incentives] will be awarded at the end of the contract," says Muley.

Nick Lewis says this means all project

parties must work together closely. "The great thing about this model is that it lends itself to creating a very good relationship with the client because we are all working towards the same objectives," he says.

The team involves project manager Aurecon, formerly Connell Wagner, and permanent works designer is the local GHD. "The way the term contract is set up is that we all worked together to design the alignment and the permanent works with GHD prior to contract award. Since award we also worked with Halcrow Pacific Pty to carry out the temporary works design." The



Right: Map of the new and existing sewer routes and (inset) the route of the trunk sewers to the Werribee works





client's checking engineer for the geotechnical works design is Golder Associates and checking engineer for the structural design is Parsons Brinckerhoff.

Not surprisingly given its age the existing sewer is now leaking with both ground water seeping into the pipes and sewage leaking out. "It is a 120 year old sewer constructed out of cast iron and brick lining in sections. It is well undersized and needs to be renewed," says Lewis.

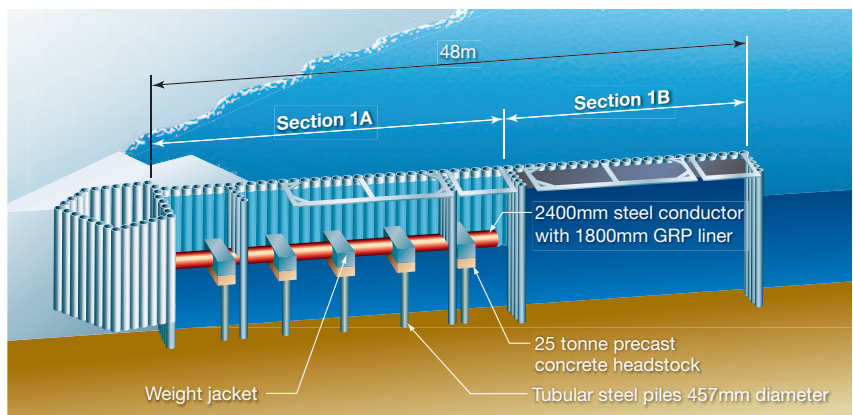
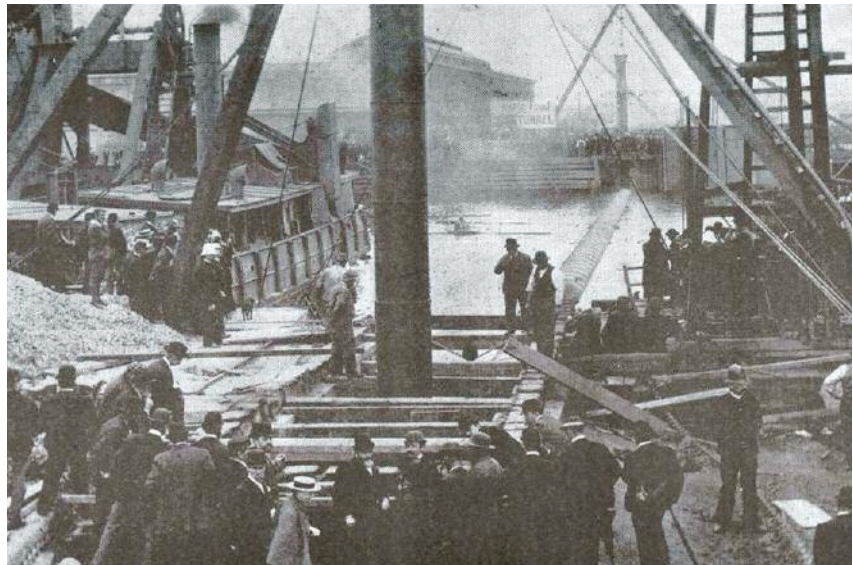
This means intercepting the existing sewer and replacing a 2.3km section with a new 1.8m internal diameter glass reinforced plastic pipe, that sits in the 2.4m i.d. concrete tunnel, bored with the 3m diameter EPBM. The gravity sewer will run at an average gradient of 1:750.

The two interception points are at Wurundjeri Way to the North of the City, and Swallow Street in the south, just before the existing sewer joins the Hobson Bay Main, which is the large collection sewer that takes flow to the Werribee treatment works (see map). "Those two interception points are two of the key challenges; sinking a temporary shaft over an existing sewer which might be in a poor condition. We have done it successfully at Swallow Street and this shaft also forms the reception point for the tunnel boring machine going south," says Lewis.

Due to the proximity of two existing utilities the team opted for a hexagonal shaped reception shaft using diaphragm wall construction down to a depth of 15m. Then a further polygonal section tunnel connects from this shaft to the existing sewer. A sub contractor in ground improvement, Menard, built the diaphragm walls. "We have been able to maintain tolerances and take the diaphragm walls within 500mm of the existing sewer, which was cast iron in that section," explains Lewis. "So we have got parallel walls running along the side of the existing sewer at that end of the project and we fill in the gaps between the existing sewer and the diaphragm wall using jet grout." This grouting was carried out by another ground improvement specialist Keller to create a plug that keeps access to the existing sewer dry, however the team knew that once they reached the 120 year old pipe it could be wet depending on condition. "One of the key risks was that there might have been water flowing down the outside of the pipe, but having exposed the sewer we have found it to be very dry," says Lewis.

**First bore**

So with the first hurdle cleared the next step for the team was to launch the EPBM



**Opposite:** The Lovat EPB TBM being readied for the first bore

**Top:** Building the original Melbourne Main sewer in the late 1880s

**Above:** Fig. 1. Schematic of staged dry coffer-dam method of crossing the Yarra river

and complete the first bored section, from the Fennell Reserve Shaft down to Swallow Street, a distance of approximately 1.1km. It was launched in September 2009 and is expected to break into the Swallow Shaft later this month (mid-June) having already completed 90 per cent of the bore. The machine is lining the tunnel with a 2.4m diameter, 200mm thick, concrete ring made up of five segments plus key. "That is probably as small as you would want to go without opting for a remote EPB tunnel boring machine," says Lewis. "Pipejack options were reviewed during the alignment design but due to all of the obstacles along the way such as the piled foundations of the Westgate Freeway and the South Wharf retail development, it was determined that a segmentally lined tunnel was the only viable solution."

To date the 92m long, EPBM with its 16 roller cutters, is boring through the Coode

Island silt at approximately 8.8m per day. "Our record to date is 14m in an 11 hour day," says Lewis. Overall bore progress has been slightly slower than the team had hoped, however the machine was launched six months ahead of schedule to mitigate any delays caused by the challenging ground. "So we are still ahead of contract programme," says Lewis.

One of the issues that has caused delays is the hydrogeological properties of the ground. "This part of Melbourne has not been mapped for its hydrogeological connectivity and we have basically taken a lot of information from this project and developed a very good understanding of the hydrogeology of this part of Melbourne," says Lewis.

In late 2008 the main drive shaft at Fennell Reserve was sunk in a basalt island in the soft ground, but the highly fractured clay is also extremely permeable. The



Left: Nick Lewis - project manager

resulting drawdown of water at the site led to some design changes during excavation which involved significant ground treatment. "There is a significant risk with drawing water from geology that is connected to Coode Island silt because there is the potential for depressurisation which can lead to consolidation – not that we have seen that to date, but when we sank this shaft we had to rethink some of the design."

This led to the team installing a combination of jet grouted canopy tubes to support a layer of Port Melbourne sand

## Crossing the Yarra

Crossing the river is a major section of the project and, due to the extensive amount of dredging that the river has already experienced, tunnelling was not a viable option. Instead the team planned a staged wet cofferdam construction sequence. "We did it in three stages to keep the river navigable to traffic, and in the event of a King Tide and a 100 year storm we have to ensure that there would not be flooding in central Melbourne upstream of our construction work," says Lewis.

This was changed from a dry cofferdam because of the hydro geological risk of driving piles down into the gravels of the river bed. "It was realised that to maintain a dry cofferdam with water trying to get in we would probably struggle to maintain it. By moving to a wet excavation it has produced a very good value engineered solution for us and the client." The first of the three stages was a 48m length starting at the south river bank. The cofferdam was installed with sheet piles and bracing before being split into two sections 1A and 1B (figure 1). Excavation of section 1A then began and area B was used to store the excavated material. Installation of ten, 457mm diameter steel tubular piles then began and these were driven down to 24m below bed level. These were then cut and a coupler installed before the precast headstock which would serve as the bed for the 2.4m diameter steel pipe. The pipe itself was split into three sections in phase 1A with a 6m length, a 9.8m length and a final 9.8m length. These were bolted together at the flange before the pre-cast weight jacket was installed above the pipe lengths. The area was then backfilled using material from section 1B and the process then begins again. This same method will be used on the second and third 45m long sections until the steel pipe is complete before the 1.8m diameter glassfibre-reinforced (grp) liner is installed.

sitting approximately 2m above the launch shaft, with polyurethane injections made into the base of the excavation.

Another challenge for the team to consider is what happens to the 164-tonne EPBM with its 74-tonne cutter head in the soft ground once boring stops in the evening. Restricted working hours mean that boring starts at 7:00 and finishes at 18:00. To prevent any settlement the EPBM has been fitted with a sophisticated Allen-Bradley PLC (programmable logic controller) system which sends text messages to the team if there are any changes in parameters experienced by the machine. "We had a couple of sleepless nights when we were setting the parameters for the alarm system but to date it has all been very successful," says Lewis. As an added precaution the machine also has an automated bentonite injection system that will inject bentonite around the machine to maintain the annulus and help control EPB pressure overnight.

## The relaunch

Once the EPBM completes this bore next month it will be retrieved and taken back to Fennell Reserve where it will then be launched in the opposite direction moving 960m north towards the Yarra River. The next major challenge on this leg is the presence of hard basalt. "The GI (ground investigation) shows there will be a very hard basalt finger, so we may well carry out an intervention within the Johnson Street shaft to inspect the head and make sure the tooling is OK," says Lewis. The EPBM has mixed face tooling involving both rippers and cutters as some hard ground has been encountered in the current section. To date two interventions have been carried out to check the tools which all appear to be in good condition. Lewis says that the team may decide to use cutters only between Fennell Reserve and Johnson Street before replacing rippers as the machine nears the river. This is because there is a chance that the EPBM will meet some previously installed obstructions such as timber piles that supported old timber wharfs.

The final destination for the EPBM, named Lucy Loo by a pupil at the nearby Port Melbourne Primary School, is the south bank of the Yarra River. To remove the machine from the shaft a crane will be fitted to the Charles Grimes Bridge in January/February 2011. This bridge carries the four lane docklands highway over the Yarra River.

Although this milestone represents the end of the EPB bore there is still the river crossing (see box) and the final short pipejacked section to complete, along with 2.5km of connection pipework (reticulation sewers) to divert all effluent into the new pipeline. These 300-600mm diameter pipes sit at depths of 3-10m and will require a total of 28 temporary access shafts to place, which will later become manholes.

The last section is the 1.5m internal diameter, 46m long pipejacked tunnel, sitting around 15m deep, between the shaft in the central reservation of Wurundjeri Way and the shaft at the north bank of the river. Lewis says this will be a relatively straightforward activity due to the soft ground and small pipe length. A auger-boring machine from US supplier Akkerman is being used for this activity and some of the reticulation sewers.

Finally connecting the new sewer in to the second interception point at the northern end of the site will be particularly challenging as the shaft sits in the middle of a highway. The potential for disruption means that there is a time constraint built in to the contract that says the team must be in and out of this location within 12 months. The methodology for exposing and breaking into the pipe will be similar to that used at Swallow Street. "We are going to be closing a lane either side of the road and use the central reservation," says Lewis. This activity is due to start in January 2011, for completion in January 2012 and will see diversion of up to 1000 litres of sewage per second at peak into the new sewer.

As part of the decommissioning works the team will access the existing sewer via the ten existing access shafts and backfill it with foam concrete. "If left to continue leaking it would pose a risk to Melbourne," say Lewis.

At the same time they will also decommission the North Wharf pumping station which is an emergency facility on the existing main and is designed to pump waste directly from the MMSR into the Yarra in the event of an emergency blockage. Instead flow will gravitate to the Werribee works eliminating any need for effluent to overflow into the Yarra.

Completion of the scheme is scheduled for 2012 when residents of Melbourne will benefit from the new, improved sewer network. The earlier the better for all parties involved as the team works towards achieving the incentive payments promised by client Melbourne Water. "Currently we are on track to achieve the target cost and we expect to make some cost savings at the end of the project," says Muley.

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# A guide to education

With growing concerns of a mounting skills shortage as the numbers exiting the industry outweigh those entering it, Nicole Robinson looks at what options there are for training tunnellers

**W**hen professor Jamal Rastami came to Penn State University in 2007, the mining program had 24 students. That number is now more than 50, and growing, he says. Graduates typically go into the mining industry, but in the past couple of years they have been receiving offers from tunnelling contractors or consultants and are making their way into the tunnelling industry. “Our graduate program is very limited when it comes to this topic. I have four graduate students and three of them are more or less involved in the tunnel industry and related research work,” he explains.

Much like the workforce it provides, university-level education for tunnelling and underground construction is in short supply. Also increasing the demand for education is a confluence of engineers from different applications into the tunnelling industry due to the economic crisis—most of which need more background before they can work underground. Universities in both the UK and the US offer courses related to tunnelling in their civil, mining or geological engineering departments, but there are no tunnel-specific degrees.

That is hopefully going to change in the next few years. Warwick University in the UK is in the final stretch of approving an MSc in Tunnelling and Underground Spaces. In the US the Colorado School of Mines plans to start offering a minor in tunnelling for undergraduate students within a year’s time, and possibly a master’s after that. Rostami at Penn State has been working on curriculum for a tunnel engineering master’s that could start as soon as 2011 with the right support. Meanwhile Priscilla Nelson, a professor at the New Jersey Institute of Technology, suggests the industry needs an executive management degree in underground construction (see page 17)

In Europe, master’s courses are being offered, not always in English. Many of these operate with the support of industry sponsors who provide lecturers and often funding. This concept is also used for the Online Certificate in Tunnelling through the

University of Texas at Austin, which is open to the school’s graduate students and engineers in the industry who are interested in tunnelling.

The problem that comes up, says Ray Henn, adjunct professor at Colorado School of Mines, is “what should a tunnel engineer look like? What educational background should they have?”

Many universities don’t yet have the courses available nor the expertise to teach them. Undergraduate students already have very limited space in their curriculum to add credits, and don’t want to stay more than four years in school, he points out. But the interest is there. “I taught tunnelling this last semester and had 32 total students, half of which were from the civil [engineering] department,” he says. “So I think it’s just a matter of spreading the word. The students are genuinely interested, but they haven’t really been exposed to the profession of underground construction.”

The Colorado School of Mines just started the first student chapter of the Underground Construction Association (UCA), and that was a grass-roots effort, one on the students’ part, explains Henn.

It’s not only attracting students into education that’s important, says Dave Klug, UCA chairman, it’s also about continuing their development. “Once you get them into the industry, then you have to make an effort to get them on the projects and expand their horizons. Get people exposed to new technology.”

Looking outside of academia, it’s just as challenging to attract younger vocational workers into the field. And perhaps even more so because many potential workers may not attend universities and need to be recruited directly from high school. Couple that with a different lifestyle, one that requires workers to move often, which creates challenges for young families.

One of the steps the UCA is taking is opening up a vocational scholarship programme. But to reach potential workers and young engineers, Klug says, “That’s something any one organisation—whether it be the UCA, BTS, Tunnel Association of Canada—cannot do.”

He explains, “If the design firms want

engineers, then they have to go out and create their own programmes to attract them. If the contractors want technicians then they have to develop their own internal programme to go out and get them.

“Every sector of the business has to make an out-reach effort.”

Whether it’s starting a scholarship programme or donating to one, starting a summer internship programme for engineering students and getting them involved beyond fetching coffee, or hosting student days at all levels of education.

That’s very much what’s happening in the UK, where it’s well-established that the industry faces a shortage of workers with the skills required to work in tunnelling and underground construction. To help address this, the Crossrail Tunnelling and Underground Construction Academy (TUCA) is being developed to provide training. And while TUCA will initially be available only to employees of Crossrail contractors, the idea is to have an independent organisation once the project is complete. In the future Crossrail says it will work with further education colleges to develop a foundation degree that incorporates tunnelling-specific material.

In addition, various schemes have been developed to set a standard of competence for Nozzlemen. Many of these programmes have been devised at the request of contractors and project owners. The European Federation for Specialist Construction Chemicals and Concrete Systems (EFNARC) scheme launched autumn 2009. “It came from our members,” says Roland Harbron, president and secretary-general. Because they have control over quality when it comes to the chemicals and materials, but the one thing they couldn’t control was the quality of the spraying, he explains.

Organisations across the UK and the US - the British Tunnelling Society Young Members and The Moles are two examples - are going into both universities and high schools, doing presentations and reaching out to students. “There is a saying, ‘Get the job and they will come.’ ‘They’ meaning the workers,” says Klug. “That scenario does not hold true anymore.”

## University and Continuing Education:

### Politecnico di Torino, Italy

Politecnico in Torino (Turin) offers a Post Graduate Master Course in Tunnelling and Tunnel Boring Machines, which is endorsed by the ITA. The official language for the course is English, and it is open to graduates with an MSc in engineering and geology.

The programme is currently running its 2009/2010 session, which will finish in October, and the school expects to start another edition in autumn 2011. Much of the curriculum will be the same with several minor changes. For the 2009 session, there were 484 hours of face-to-face lessons and classroom exercises, two months in a tunnel construction site or in a tunnelling design company and thesis work. Lectures include presentations by experts from construction companies, machines producers, design companies and other professionals to provide multidisciplinary knowledge. A master's thesis and discussion is required before students can receive the course's master's degree.

A pool of sponsor companies provide guest lecturers and in some cases financial help. The faculty is evenly split between academic and sponsors. In the duration of the course there are three modules, tunnel design and construction methods, mechanized tunnelling and management and safety of job sites. There is an option for professionals to apply for just one of the three training modules, but all of the dates have lapsed for the 2009/2010 session.

[www.tunnel.formazione.corep.it/tunnel09/index.html](http://www.tunnel.formazione.corep.it/tunnel09/index.html)

### Ruhr-University Bochum, Germany

The university's Institute for Tunnelling and Construction management, headed by Dr Markus Thewes, offers BSc and MSc programmes in civil engineering, and at the master's level it offers a specialisation in geotechnics and tunnelling. Most coursework is in German.

[www.tlb.ruhr-uni-bochum.de](http://www.tlb.ruhr-uni-bochum.de)

### Spanish Association of Tunnels and Underground Works (AETOS), Spain

AETOS developed a master's specialisation with support and sponsorship from numerous industry agencies and companies, and with approval of the ITA.

The main objective is to provide the technical skills needed to enter the professional world in regard to planning and project, and or construction management. It offers specialised training for professionals already working in tunnelling, and students wishing to pursue research and or teaching.

Applicants must have a university degree (or equivalent), and prior knowledge in underground works is preferred. The course is held in Madrid, directed by professors from the Polytechnic University of Madrid and conducted in Spanish.

[www.master-aetos.com/](http://www.master-aetos.com/)

### Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland

The Master of Advanced Studies (MAS) on Tunnelling at EPFL is an advanced training programme, jointly organized with and endorsed by the ITA. MAS Tunnelling runs every year and is conducted in English by international experts and specialists from universities and industry. Students complete four modules that aim to provide high quality training covering theory, analysis, design, construction and practice.

MAS Tunnelling is for individuals who wish to progress their career in the tunnelling industry and for companies that wish to advance their engineers' knowledge and potential. The minimum enrolment requirements are a Bologna master's diploma degree (Europe), or a minimum 4-year bachelor's degree (non-Europe), or equivalent, and a minimum of three years experience working in tunnelling or tunnel-related construction engineering.

The programme is administrated by the Laboratory for Mechanics of Rocks in EPFL and directed by Professor Jian Zhao. The next edition is set to start in January 2011 and end in autumn 2011. Applications are being taken now.

[lmr.epfl.ch/page64027-en.html](http://lmr.epfl.ch/page64027-en.html)

### Norwegian University of Science and Technology, Norway

NTNU offers a number of degrees that span the fields associated with tunnelling: structural engineering, geotechnics, geology and civil/transport engineering. And there is a two-year master's degree in geotechnics and geohazards taught entirely in English that includes a component on tunnelling. Specific to tunnelling and underground construction, NTNU offers a continuing education course, "Engineering geology for construction managers in the underground works." However this option is only offered in Norwegian.

[www.ntnu.no/](http://www.ntnu.no/)

### The University of Texas at Austin (UT), USA

Fulvio Tonon, a professor at UT, has developed the Online Certificate in Tunneling with the International Tunneling Consortium (ITC) to bring academia and the industry to a common table. The programme is ITA-endorsed and the certificate is open to UT graduate students and members of the tunnelling industry, worldwide. There are 11 modules that students go through in duration of no more than two years. All lectures are recorded and posted online, including those made by guest speakers. By doing the course online, says Tonon, members of the industry can participate without leaving their jobs or moving.

Companies join the ITC for a fee and in return can take advantage of research done by students in the certification programme, access the pool of students for recruiting and internships and enrol their employees in the course at a discounted rate.

The consortium has two aims, research and education, explains Tonon. "Of course they [companies] can do some research or they can have their own R&D," he says. "But sometimes they're limited in what they can pursue both in terms of time and human resources. And what universities do well is research, in terms of having students that do research in depth for an extended period of time."

Companies from the ITC suggest basic ideas and brainstorm with UT to find topics that can be researched in a three-year cycle. "We're completing the first research cycle that we started in 2007 and we are trying to understand what topics we'll be investigating in the next three years 2010-2013," explains Tonon.

The Online Certificate in Tunneling will start again on 1 September, and online registration is open. If there is strong demand the programme will run every year, otherwise it alternates years.

[www.cae.utexas.edu/](http://www.cae.utexas.edu/)

### British Tunnelling Society (BTS)

Annually, the BTS offers a five-day Tunnel Design and Construction course and a two-day Health and Safety course.

This year's Tunnel Design and Construction course runs 5-9 July at Warwick University in Coventry. The purpose of the course is to provide a comprehensive introduction to all aspects of tunnelling—ideal for young consulting engineers and construction engineers in the start of their civil engineering careers, but not limited to them. It is aimed at the range of professional services supporting the tunnelling industry, including clients, tunnel operators and members of the financial and insurance sectors that may have a vested interest in tunnelling enterprises. The course is in English and open to attendees worldwide.

The course will follow the project life and will contain worked examples and workshop sessions to allow improved interaction between delegates and speakers. Industry best practice will be presented by leading experts in the various technically challenging fields of tunnelling technology with special emphasis placed on health and safety.

More information and the registration form are available online. The 2010 Health and Safety course will be held 22-23 November; more information will be available shortly.

[www.britishtunnelling.org.uk/](http://www.britishtunnelling.org.uk/)

### Colorado School of Mines

The Colorado School of Mines currently offers classes geared to tunnelling or underground construction and plans to offer a minor in tunnelling for undergraduate students in mining engineering, civil engineering and geological engineering majors starting in September 2010, or January 2011.

Separately, the school offers three annual on-campus short courses geared toward the tunnelling industry. There is a four-day Microtunneling short course (the 2010 session was held in February) and a five-day Grouting course being held 7-11 June 2010.

A three-day tunnelling short course is planned for 22-24 September 2010 that will cover all aspects of conventional and mechanized tunnel design and construction in hard rock, soft ground and soils.

Participants may still register

[www.tunneling.com/tunneling\\_course\\_basic\\_outline\\_2010.htm](http://www.tunneling.com/tunneling_course_basic_outline_2010.htm)

[www.mines.edu](http://www.mines.edu)

### Warwick University, UK

A proposal for an MSc in tunnelling and underground spaces is presently going through the approval process at Warwick University. The course will be aimed at people with bachelor's degrees in civil or mining engineering, and would offer space for up to 25 students a year. With approval from the Board of Graduate Studies the first intake would be October 2011. A decision will be made in June.

[www2.warwick.ac.uk/](http://www2.warwick.ac.uk/)

## Shotcrete Education:

### Hagerbach Test Gallery, Switzerland

Hagerbach is an underground infrastructure with tunnels totalling approximately 5km in length and gallery cross-sections up to the size of a two-lane motorway tunnel. The facility comprises galleries, caverns, test sites, laboratories, conference rooms and tourist attractions. The venue provides a multitude of opportunities like research and development for underground construction, rock and concrete lab tests, training and special events.

Hagerbach offers training courses for different levels of staff for underground construction—on both a fixed date basis and upon request—that run from one day to one week. The facilities may be used independently for seminars or training by third parties. Hagerbach can provide as little or as much equipment and trainers as necessary. Trainers speak English and German, though all language requirements are accommodated through translators. To hire space, two- or three-months notice is appreciated, though certain times of year are less busy, like prior to Christmas or Easter break. Trainers are also prepared to travel to job sites for shotcrete sessions.

During 2010, Hagerbach will offer a shotcrete course on 1 September and a conference on waterproofing on 26 October. These are planned to be held in German. The EFNARC Nozzleman Examiner Certification in October will be held here as well.

[www.hagerbach.ch](http://www.hagerbach.ch)

### American Shotcrete Association (ASA)

Separate from the ACI certification scheme, the ASA offers an Underground Shotcrete Education Program. ASA's education committee put together the programme because mine operators, tunnel owners and constructors expressed an interest in educating the work force that uses shotcrete to improve and ensure the quality of their projects.

A contractor, tunnel owner, or other interested party contacts an Educator (listed on the web site) directly to arrange an on-site session, which can range from one to several days. The programme provides the basics of the shotcrete process, including materials selection and testing, basic equipment requirements, skill requirements for the nozzlemen and crew, proper shotcreting techniques and safety.

[www.shotcrete.org](http://www.shotcrete.org)

### European Federation for Specialist Construction Chemicals and Concrete Systems (EFNARC)

EFNARC launched its Nozzleman Certification Scheme in September 2009 for wet, robotic sprayed concrete.

The programme is not a training course; it offers certification to nozzlemen who have already gained the necessary experience and can demonstrate their technical knowledge and practical ability. Anyone wishing to obtain the certification or certification on their project should contact their nearest examiner, listed on the web site. Examiners hold the one-day assessment at the nozzlemen workplace, and it covers both theoretical and practical skills at their workplace.

Expert nozzlemen with considerable experience in sprayed concrete application can apply to be examiners. This includes attending a two-day assessment and accreditation programme offered at Hagerbach Test Gallery. Like the certification scheme, this is not a training course. Participants will go through their own assessment, discuss theoretical issues, sprayed concrete application and approaches for examining nozzlemen.

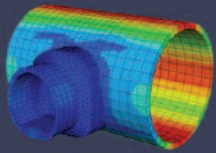
The next Nozzleman Examiner Certification is 5-7 October, 2010. There is an application online and registration closes on 1 September. [www.efnarc.org/Nozzleman\\_Certification\\_Scheme.html](http://www.efnarc.org/Nozzleman_Certification_Scheme.html)

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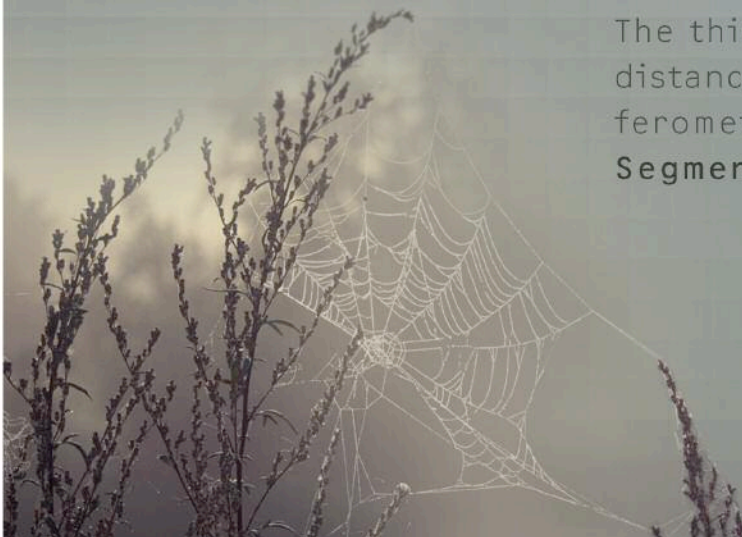
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# 1 $\mu\text{m}$

The thickness of a spiders web and the distance resolution of the Laser Interferometer used in VMT's Mould and Segment Measurement system.



### The American Concrete Institute (ACI)

ACI established a shotcrete nozzleman certification programme to establish a basic skill level of shotcrete nozzling. Education and testing are provided by sponsoring groups authorized by ACI, like the American Shotcrete Association (ASA), and ACI issues the shotcrete nozzleman certificates.

There are two options for certification, dry-mix and wet-mix. For both, basic knowledge of shotcrete construction is required, such as shotcrete placement, principles and techniques; basic concrete technology; environmental conditions and precautions; inspection and preparation of surfaces; safety and curing.

There isn't a specific education prerequisite for the certification, but applicants will need to verify 500 hours of work experience as a nozzleman or nozzleman-in-training in order to participate in the examinations. The written test is 90 minutes, multiple-choice question and closed-book. The performance exam requires nozzlemen to demonstrate knowledge of everything from surface preparation to finishing and curing. The examinee must place dry-mix shotcrete in the vertical position and has the option to also place dry-mix shotcrete in the overhead position.

ACI will grant certification only to applicants who receive a passing grade on both the written exam and successfully complete the performance exam. Recertification is necessary every five years, and requires successful completion of both an oral interview and performance examinations.

[www.concrete.org](http://www.concrete.org)

## Vocational Education Opportunities:

### TunnelSkills

TunnelSkills is a specialist training forum set up by contractors, sub-contractors and labour suppliers of the industry to try to raise the standards of competence. It developed the Safety Passport Scheme to ensure a level of knowledge of underground safety consistent with the knowledge requirements of NVQ Unit VR01 – Conform to General Workplace Safety. All persons working in the tunnelling environment will be required to renew the Safety Passport at two-year intervals.

Candidates for the passport must have passed the CSCS H&S Test in the past two years, and have or be working towards an appropriate qualification relevant to working in the tunnelling environment. The minimum for this is an NVQ Level 2 in Tunnelling Operations. To obtain the Passport, a candidate must do at least one day of training with an approved trainer, which culminates in a test or assessment of 45 questions from the training syllabus and requiring an 80% pass rate.

TunnelSkills authorises trainers, sets the assessment questions and issues the certificate.

Register online at [www.tskillspassport.org/](http://www.tskillspassport.org/).

### Crossrail Tunnelling and Underground Construction Academy (TUCA), London

Groundbreaking should be held in the next few months for a purpose-built facility at Aldersbrook Sidings in east London. The academy will provide training on the key skills required to work in tunnel excavation and underground construction. Curriculum is being developed now and it is expected that students can enter the academy in early 2011. Initially the academy will not be open to the public and participants will need to be employed by one of the contractors working on the Crossrail project.

Most of the training provided at the academy will be through an NVQ Level 2 in Tunnelling Operations. The modules being developed provide opportunities for rotational training, which could form part of an NVQ or Apprenticeship in tunnelling, and opportunities for contractors to up-skill their staff with training on specific areas of the tunnel environment. The academy will also ensure that all people working underground will have achieved the TunnelSkills Safety Passport before working on Crossrail sites.

### Mainport Training

Mainport Training offers an entry to tunnelling course. Devised with help from Newham Workplace and TunnelSkills, among others, the programme is essentially a package of modules. These can be taken in entirety (nine days), or in a more bespoke arrangement, depending on a participant's previous experience.

The courses include, Introduction to Tunnelling, the TunnelSkills Safety Passport, First Aid (one day or three days), a Confined Spaces to City & Guilds certificate (normally medium risk two days), Cable Avoidance Tool, Traffic Marshall and the Slinger Signaller course can be added on as well.

The package of courses is open to anyone, and Mainport expects to run at least one per month in east London and perhaps at other centres in the future.

[www.mainporttraining.com/](http://www.mainporttraining.com/)

## Conference Options:

### North American Tunneling Conference (NAT)

The North American Tunnelling Conference is offering four short courses on 20 June: Grouting in Underground Construction, Soft Ground Tunneling, Shaft and Tunnel Blasting and Shaft Design and Construction. [www.smenet.org](http://www.smenet.org)

### International Tunnelling Association (ITA)

Short course training sessions run prior to the ITA World Tunnel Congress each year. Next year's 2011 Congress in Helsinki, Finland will have courses on May 20-21.

[www.wtc11.org](http://www.wtc11.org)

### Rapid Excavation & Tunneling Conference & Exhibit (RETC)

Short courses will be held with the June 19-22, 2011 RETC in San Francisco. Further information will be available closer to the date.

[www.retc.org](http://www.retc.org)

### Possibilities in the pipeline:

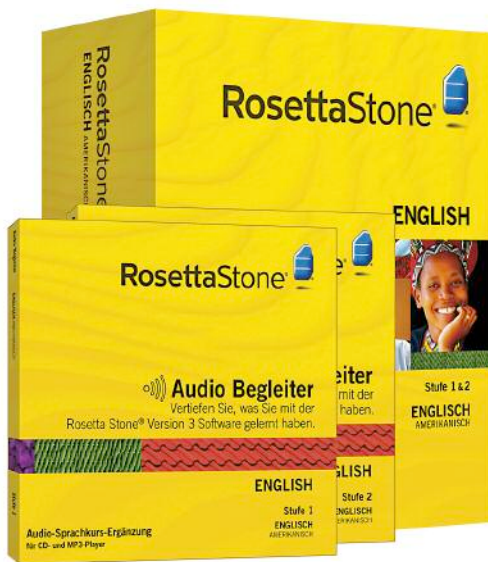
- At Penn State University professor Jamal Rostami is in the process of setting up a tunnel engineering programme at the master's level, hosted in the civil engineering departments. He says this could start as

early as fall of 2011 with industrial support.

- The American Shotcrete Association's education committee is working with the American Concrete Institute to start a certification programme for shotcrete inspectors. It could be a year or more

before it is set up.

- The Colorado School of Mines is in the preliminary stages of putting together a graduate degree that would read tunnelling engineering. Students could earn a master's or doctorate degree. ■



# Gift of the gab

Clear communication is crucial to any underground construction project and the global nature of tunnelling means there is frequently more than one language spoken on site. Jon Young looks at one method of improving communications: a language course

**W**ith tunnelling projects often drawing on labour and expertise from all over the world it is not unusual for a tunnelling site to have more than one language being spoken on it. Being able to speak the languages used on site is unarguably an advantage and one company that is targeting the tunnelling sector is Rosetta Stone.

The language experts are offering the service as a company resource so that tunnellers can be taught a language before heading off to site. To see if the course delivers on its promises of rapid language learning T&TI tried the programme out.

The course is taken online or using a CD. It works by trying to emulate the way a child learns a language, through total immersion, but accelerated. A typical course is broken in to three to five levels. Each level is broken into four lessons and each lesson into four or five units.

The unit is launched with a 30-40 min session that covers everything the unit will involve. Then subsequent session reinforces what has been learnt in the first session but with a particular focus, such as grammar, pronunciation, spelling, speaking or listening.

A typical example would be seeing four pictures: a boy with a ball, a man with a

ball, a man with a cup and a girl with a cup. A voice will describe a picture in the language you are learning, in T&TI's case Swedish, and the object is to click on the correct picture. The course rarely becomes more complex than that.

It is an effective way of learning as it builds understanding through repetition and does not rely on memorising or drills. This promotes a level of competency in the language that is based on understanding the structure of the language and not simply remembering phrases.

The course takes anything from one to twelve months depending on how many hours can be committed each day. ▀

 The image shows a construction worker in a red hard hat and a high-visibility vest standing next to a large, blue and red mechanical component, likely part of a tunnel boring machine. The worker is looking at the component with interest. The background shows a construction site with a chain-link fence and some equipment.
 

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# The benevolent ‘big brother’

Means of monitoring what is going on in transport tunnels are rapidly becoming more sophisticated. Tunnel monitoring and control systems not only have to provide and interpret accurate information in a sometimes harsh environment, they have to prioritise this input and initiate the best actions for users’ safety and operational economy. Maurice Jones reviews some of the latest developments towards these ends.

**T**ypes of tunnel monitoring and control system can range from virtually nothing to complex interactions of values, images and sounds that have to be made sense of. Once this array of information has been prioritised, the system may need to initiate actions, whether manually or automatically, with the aim of maintaining the safety of those using or working in the tunnel, guarding against any threats to security, and maintaining an optimum level of operational economy. In all of this, tunnel operations have to cope with the far from predictable behaviour of the public, fires and fumes.

Operational complexity generally increases with the number of passages included, their length, junctions, and the levels and variety of traffic. The type of traffic, such as freight vehicles, may include potential and often unknown hazards.

For all but the least trafficked tunnels an operational decision-making framework is necessary, not only for the different variations of ‘normal’ working, but all foreseeable types and locations of hazardous situations. In addition to the tunnel operator’s own staff the framework should include and be integrated with the plans of any necessary outside organisations such as fire and rescue teams, police and contractors.

During ‘normal’ operation the tunnel control system has to manage situations such as:

- night and day operation;
- other light changes due to weather variations;
- high levels of usage producing excess exhaust emissions or dust;

- extremes of temperature with possible freezing or mist creation;
- user vehicle breakdowns;
- maintenance access required to equipment and tunnel bores.

Fire has naturally dominated safety and tunnel operational design thinking in recent years. The usual causes are hot or ignited materials being brought into the tunnel on vehicles or collisions (especially with flammable loads or large fuel tanks). However, there are many other scenarios of possible emergency incidents. Non-fire incidents can include:

- vehicle collisions, possibly involving hazardous materials – permitted or illegal;
- large fuel, lubricant or chemical leakages;
- failure of the tunnel fabric or equipment;
- erratic/dangerous driving including driver health failures;
- terrorist or similar threats or malignant actions with dangerous materials involved.

## Integrated control

There are many different types of monitoring devices to check and measure environmental conditions and hazardous incidents, and of course tunnel equipment has its own control systems, but relatively few companies supply complete control systems. One company that does is Siemens.

In its systems each alarm has a priority flag. The tunnel operating system has an alarm management protocol that works through the alarms according to the priority flags and current incident level.

The control systems of tunnel equipment can be interlinked with automatic



responses programmed in, where meaningful. However, according to Siemens, many tunnel owners and operators still prefer to initiate incident responses manually, including during an emergency. The current trend is towards semi-automatic systems that allow the tunnel operator up to one or two minutes to initiate a response, or failing that there is a preprogrammed response.

Siemens also supplies control systems to help reduce the number of traffic jams, and thus tunnel congestion and queues, with optimised traffic flow guidance. This is no small achievement since, according to the Federation of German industries, clogged roads cost over EUR1bn (USD1.2bn) a year in Germany alone, and obstructed tunnels can be a particular problem. For example, dealing with breakdowns and fires is considerably more difficult in tunnels than on open highways.

Siemens has developed a system that recognises overheated truck brakes, even before tunnel entry, so that an alarm can be sounded in the event of danger. Also, a radio-frequency identification (RFID) system registers information regarding the contents of vehicles with hazardous, or even high-fuel, loads, and relays the information to the control centre so that fire services have the appropriate extinguishing agents on hand should fire break out. Tests of the new system were due to begin in the



**Left:** The Vicotec smoke and noxious gas detector from SICK-Maihak  
**Above:** Testing the components of Siemens' RFID system to identify hazardous loads  
**Right:** Infrared image of a truck before tunnel entry showing hot spots [Siemens press photo]



Aubing Tunnel near Munich.

Siemens systems are also used in many other tunnels' fire protection systems in tunnels on Zurich's A3 western bypass and the A4 link between Zurich and central Switzerland.

P Ducker Systems (PDS) has also developed a road tunnel monitoring system fully integrating plant light, video, audio, ventilation, electrical power, pumping and traffic data together. The Matrics system can be used to test whole tunnel systems before installation, delivering a substantial reduction in project time-scale, cost and risk, and forms the basis of all tunnel systems being installed in the A3 Hindhead Tunnel in England. PDS says that Matrics co-ordinates data to enable improved situation analysis and event response, and can be configured to provide recommended response to emergency situations where action is needed based on predetermined event plans. See below for particular reference to lighting control.

### Fire detection

Siemens fire protection starts with its Surveillance video smoke detection technology with patented edge extraction process. This enables intervention forces to gather valuable information remotely on smoke characteristics and changes inside the tunnel. For more targeted fire response

this is combined with the FibroLaser heat detection and locating system. This redundant fibre-optic cable can detect fire within one minute and pinpoint its locations within three metres of the ignition point. Each cable can be up to 4km long, divided into thousands of 'individual sensors' by dedicated electronics and software. The system is constantly tested automatically to ensure high availability.

Another cable-type multipoint heat detector, recently introduced to the market, is the SecuriSens MHD 535 from Securiton. It has been specified after tender by the Swiss federal roads office (ASTRA) for the 9.25km-long Seelisburg Tunnel on the A2 motorway, part of Switzerland's north-south transport access. When completed in 1980 the Seelisburg was the world's longest double-tube road tunnel and is still Switzerland's longest. Since its opening it has undergone a steady programme of improvement works, including current preparations for a large-scale overhaul including replacement of the fire alarm system.

The SecurSens MHD535 has numerous sensors, in clearly defined positions, that signal any rise in temperature or infrared radiation. Securiton claims ultra-sensitivity and fast response and calculation times. Apart from the cable the system also includes the cable terminal signal processor

and software. According to the software programming the processors determine whether to trigger a pre-alarm or a full alarm. Temperature values are transmitted to a management system via a serial interface. The system is reliable in temperatures of -55 to 125°C and 100 per cent relative humidity, and is maintenance free.

The fibre-optic linear heat detection (Distributed Temperature Sensing - DTS) system from AP Sensing has been the subject of field trials under authentic environmental conditions carried out in co-operation with the SP Technical Research Institute of Sweden (Koffmane & Hoff 2010<sup>1</sup>). The trials detected test pool fires within 30-40 seconds after ignition, which is about half the time required by the German RABT standards. A trial involving wooden pallets took two minutes to detect due to slower fire development. In all cases the first alarm was initiated by rate-of-rise temperature before the actual temperature value trigger point had been reached. The sensor cable survived all tests despite high temperatures, allowing continued monitoring.

In a review of current fire detection systems for road tunnels featuring the

a touch of respect



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Securiton MHD 535 cable system, Dr Arnd Rogner of Metaphysics (Rogner 2010<sup>2</sup>) concluded that for the automatic detection of tunnel fires and the subsequent initiation of cost sensitive fire ventilation and fire brigade alarms, linear heat detectors are the only 100 per cent reliable detector with a minimum of faulty alarms. However, the system must be able to react to temperature gradient since a tunnel vehicle, such as a car, cannot tolerate a temperature above 50°C.

### Visual analysis

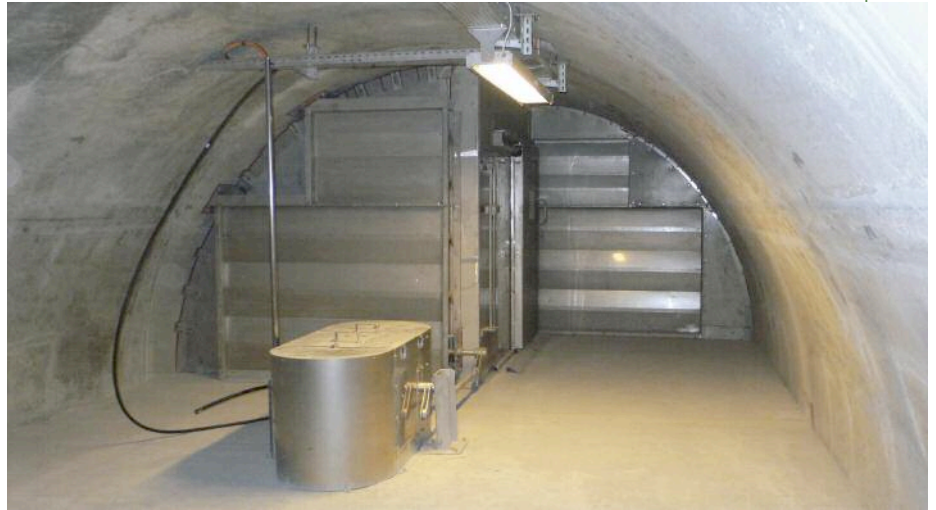
It is well known that closed-circuit television (CCTV) can be important to monitor what is going on and, with recording facilities, post-incident analysis. More recent developments, such as the previously mentioned Siemens Surveillance technology, have added various facilities for live image analysis that can greatly enhance anti-intruder security processes and for identifying unusual situations automatically.

Sound Transit in Seattle has a particular problem in controlling access to the dual-transport Downtown Seattle Transit Tunnel (DSTT) with multiple possible access points with short distances. In addition to a careful analysis of the problem (Cummins 2010<sup>3</sup>), Sound Transit is developing a solution to re-establish a 'Critical Detection Point', the lack of which is currently necessitating the stationing of a law enforcement response force to prevent any unauthorised access through a blind-spot of the normal access security officer. The solution uses CCTV and removes the human factor until the operator's attention is drawn to a specific camera or location once a set of established parameters (including unauthorised encroachment on the light rail right of way) has been met. The solution under development includes the AISight System by BRS Labs, claimed to be the world's only cognitive video analytic system. It will 'learn' the normal activity of the DSTT and recognise and alert for abnormal behaviours.

Kenneth Cummins, chief security officer of Sound Transit, has said. "This (AISight) system is different from traditional rule or algorithm-based analytic systems. The Strength is a system with less complexity and set-up criteria that results in a more adaptive, effective and accurate system reducing the impact on Link Light Rail service caused by false alarms."

### Ventilation

Correct control of tunnel ventilation fans and dampers can be one of the most difficult functions of tunnel control systems,



**Above: Actuation of ventilation dampers is an important element of ventilation for smoke control and fire oxygen starvation [Photo: HBI Haerter]**

**Right: Jet fans offer considerable flexibility in ventilation control [Photo: HBI Haerter]**

especially in emergency situations. There have been many approaches to the correct ways of fire and smoke control through ventilation, since location, fuel and oxygen availability are all vital factors. The relatively simple task in one-way road and rail tunnels (providing escape ways are clear), can be much more complicated in some underground structures.

The maximum relevant monitor data collection is therefore vital so that tunnel users can be directed to the safest escape routes and so that fire and rescue teams can be fully informed of the situation on arrival. Large tunnels may have a round-the-clock fire and rescue team present, but in most cases the local teams are trained specially to react in critical tunnel situations in the best way in co-operation with tunnel management, including on-site training.

Expert analysis of tunnel performance at the design stages, with incidents at all feasible locations, must be carried out so that emergency action scenarios and correct actions can be determined in advance. In complex situations it is possible to programme control systems for automatic actions once the location and nature of the hazard has been determined, or human tunnel operators relied upon in simpler situations.

Specialist ventilation consulting engineers such as HBI-Haerter draw up plans for both normal ventilation requirements and airflow and smoke control during incidents, including



refurbishment of existing structures with new or improved systems. In the latter cases provision must also be made for the safety of tunnel workers and users (if permitted) during temporary situations.

Ventilation can be a high proportion of tunnel energy usage. Siemens approach to keep a check on this is to calculate energy consumption on normal daily operation, and also with 'standard' incidents. In the case of major incidents requiring large increases in fan power, specific agreements are set up with local power providers.

The monitoring instrument range from SICK-Maihak includes mainly carbon monoxide (CO) determination and various environmental conditions that can be determined through visibility measurement through scattered light intensity. As a toxic gas, CO emissions from exhausts or low-oxygen combustion are one of the most dangerous air contaminants in tunnels. In addition to CO, the Vicotec range has models to determine smoke, nitrogen dioxide (NO<sub>2</sub>), nitrous oxide (NO) and general visibility. The Smotec450 smoke detector has a heated chamber for evaporation of droplets, and contamination control, to ensure correct measurement of smoke. It also has facilities for automatic control.



**Above, left:** Thorlux lighting near the portal of a road tunnel with Scanlight control from P Ducker Systems; **Above, right:** Quickly noticeable and understandable signage is vital for both normal traffic control and incident management [Siemens press picture]

The Flowsic200 air velocity measuring device has no moving parts but determines flow direction and (optionally) air temperature over tunnel and shaft diameters up to 35m. Visibility devices are also useful in controlling traffic control, including warning of inadmissible (overheight) vehicles. One such is the Hisc450, which, due to the necessity to mount it outside the tunnel to prevent large vehicle access, is protected against extremes of weather including an optional built-in lens heater to prevent condensation and icing.

Similarly the Sigrist Photometer range of instruments is used in road and rail tunnels for early fire and smoke detection, dust concentration and general visibility through scattered light intensity measurement. In the Sigrist FireGuard the scattering angle, measuring arrange, response threshold and signal processing are optimised for smoke and fire detection. There is also a

temperature sensor for localisation of the incident, and an optional heater for elimination of fog. Calibration is claimed simple even in high dust concentration.

### Lighting

Adjustment of lighting can be one of the most important functions of tunnel control under normal conditions. Variations of light at the portals, from nighttime to bright sunlight, must be balanced by graduated lighting into and on exiting the tunnels to allow drivers' eyes to accommodate the change without being temporarily blinded. Lighting control can also be important for better energy consumption economy.

P Ducker Systems and Thorlux Lighting co-operate to provide what is described as 'a reliable, energy efficient and user friendly solution for road tunnel applications.' 'Soft start', digitally dimmable control equipment regulates each lamp output according to external lighting conditions. Extended maintenance periods and substantial running cost savings are offered.

Mayer's road tunnel lighting control system complies fully with international standards published by the Commission Internationale de l'Eclairage (CIE) in order to avoid the 'black hole' effect on drivers using the tunnel. Its main components are a light sensor for continuous measurement of luminance of the tunnel entrance and portal, a stand-alone controller for automatic luminaire switching at the tunnel entrance, and an illuminance meter for measuring and recording light (incident lighting) with the tunnel to ensure lighting levels conform to specified parameters.

Optimal lighting, and consequently its monitoring, has been the subject of particular development in recent years, not only at the tunnel threshold but also within the tunnel to avoid driver boredom and fatigue. LEDs and electrodeless lamps are in development from which potential future

### Acknowledgement

Thanks to the organisers of the Fourth International Symposium on Tunnel Safety and Security (ISTTS), Frankfurt am Main, Germany, 17-19 March 2010 for references (below) to the proceedings published by SP Sveriges Tekniska Forskingsinstitut (Technical Research Institute of Sweden - Boraes) edited by Anders Loennermark and Hauker Ingason

tunnel lighting can be produced. In a recent poster session at ISTT Frankfurt (Buraczynski *et al* 2010<sup>4</sup>), the authors say that the design for the ideal tunnel lighting system should include an understanding of symmetrical and asymmetrical lighting, the various light sources, the different tunnel lighting zones, current lamp and ballast technologies, etc.

### Communications

Contacting tunnel users to warn them and advise them of correct actions during an incident have long been problematical, with conventional intercom systems often drowned out by noise in the tunnel. In road tunnels warnings can be transmitted via drivers' radios, if they are switched on as usually advised.

In metro systems GSM repeaters have been installed, as in Frankfurt (Ries, 2010<sup>5</sup>), to enable passengers to use mobile phones for emergency calls. The repeater system also covers staff handheld radios throughout the underground area. Fixed emergency phones have also been installed in a wide range of locations, allowing the caller to contact the control centre of the metro operator. CCTV connected to the control centre also monitors the phones. Existing public address was retained but brought together at a command post to enable emergency use by the local fire department.

### Signage

Another aspect of tunnel control is signage, which is very important for controlling or stopping traffic movements, and for showing users the escape routes and equipment that might help in evacuation operations. Of course for signage to have any chance of working, it must be noticed (detection), and must be understood (identification), particularly in environments of difficult visibility such as smoke.

Work has been undertaken in measuring the visibility of notices in tunnels (Schneider & Koennecke 2010<sup>6</sup>) related to size, contrast and visibility distance.

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# Trademarking the NTNU/SINTEF drillability test indices

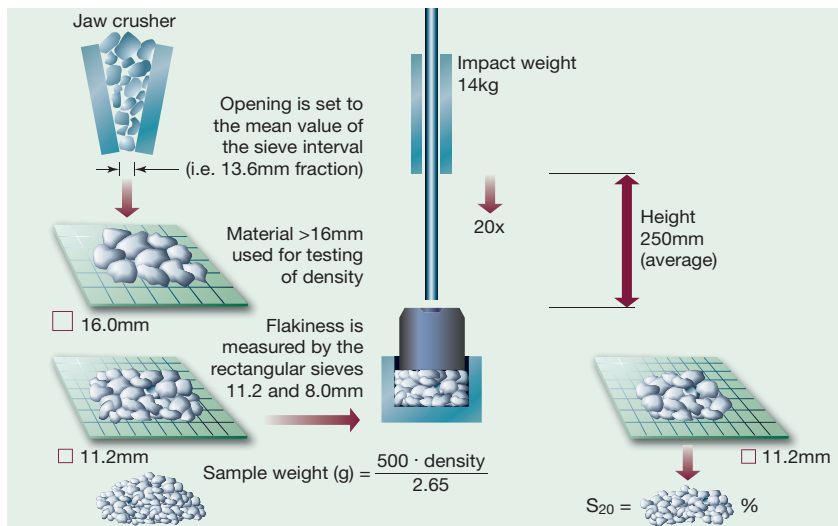
The NTNU/SINTEF drillability test method has gained international recognition as a tool for describing the characteristics of rock and soil materials regarding cutter wear and penetration rates as well as for reliable time and cost estimates. Test results originating from the reference laboratory are unique and NTNU/SINTEF has now registered the Drilling Rate Index (DRITM), Bit Wear Index (BWITM), Cutter Life Index (CLITM) and Soil Abrasion Test (SATTM) as trademarks.

**P**roducing reliable and robust prognoses on cutter wear, drilling progress and related costs are becoming an increasingly sensitive issue for machine manufacturers and contractors dealing with operation of mechanical excavation systems in tunnelling, underground construction and mining. Equally important for the clients and owners is that cost and time estimates must have adequate quality. Representative and trustworthy parameters describing the strength and abrasive properties of rock and soil are crucial as these constitute the

fundamental input for obtaining reliable cost estimates. This is equally important when it comes to risk assessments described by terms such as 'low', 'good', etc. in tender documents, and in situations where claims are filed during or following the construction period.

A main strength of the NTNU/SINTEF drillability tests is that the test results may be put into prediction models to estimate time and costs of rock and soil excavation projects. Other commonly used rock test methods do not have prediction models of the same extent available.

**Below:** Figure 1 – Outline of the brittleness test used to determine Brittle Value (S<sub>20</sub>)  
**Right:** Brittleness testing for determination of S<sub>20</sub> – close-up of impact weight hitting mortar with rock sample material [Photo: Simon A Hagen]



Recently several laboratories have set up equipment to perform the NTNU/SINTEF drillability tests. This has in some cases given highly unexpected test results; unexpected that is partly as substantially diverging results of parallel testing between other laboratories and the NTNU/SINTEF laboratory, and partly as results that are systematically outside the variation of the test results recorded in the NTNU/SINTEF database for the actual rock types.

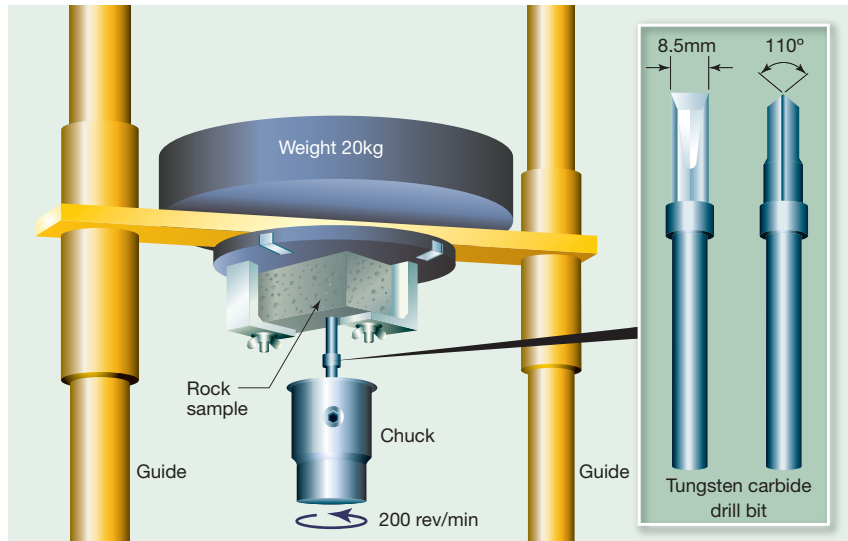
Hence NTNU/SINTEF is concerned that incorrect test equipment, procedures or results may discredit the test methods and related prediction models.

### Background

There are several laboratory test methods that can be used to determine properties influencing the drillability of rock. It is however essential to use consistent, comparable and reliable test procedures in order to achieve solid and robust prognoses and cost estimates.

The Brittleness Value (S20), Sievers' J-miniature drill test (SJ), Abrasion Value (AV) and Abrasion Value Cutter Steel (AVS) have been extensively used at NTNU/SINTEF since the 1960s in connection with drillability testing of rock samples. The Drilling Rate Index (DRI), Bit Wear Index (BWI) and Cutter Life Index (CLI), commonly referred to as the NTNU/SINTEF drillability indices, are all calculated on the basis of the above mentioned individual test methods.

Samples originating from more than 3000 projects in more than 50 countries have so



Above: Figure 2 – Outline of the sievers' J miniature drill test to determine Sievers' J-Value (SJ)

Right: Miniature drill testing for determination of SJ Value, Close-up of miniature drill bit and rock specimen [Photo: Simon A Hagen]

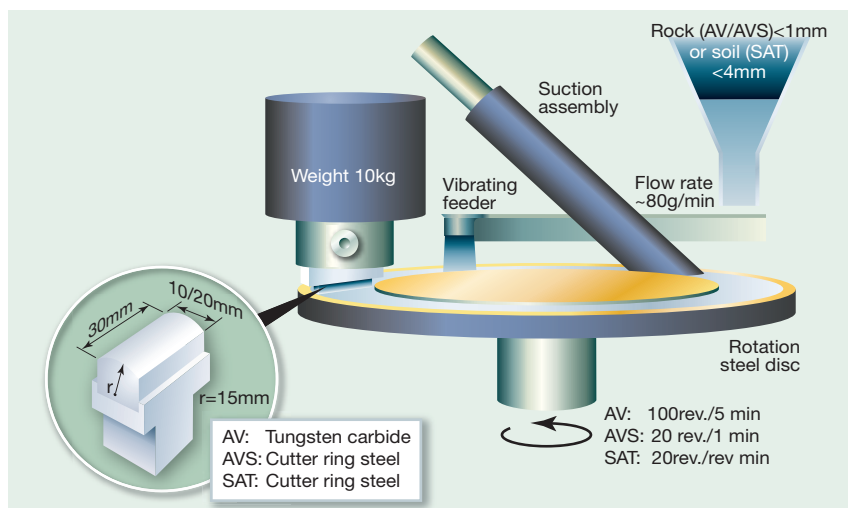


far been tested at the NTNU/SINTEF laboratory. Performance prediction and cost evaluation models for drill-and-blast tunnelling, TBM tunnelling and rock quarrying have been developed by correlating laboratory and in situ geological data with production data from tunnel projects. The models are continuously updated and revised as new tunnelling data become available. The NTNU/SINTEF method is today a recognised and widely

used test method for, for example, TBM performance prediction.

The increased demand for knowledge on properties influencing the time and cost of tunnelling has instigated further developments of the test methods. Until the development of the NTNU/SINTEF SAT [Nilsen et al, 2007, 1], very limited knowledge was available to describe the abrasiveness of soil and its impact on soft ground TBMs. The

Below: Figure 3 – Outline of the abrasion test used to determine Abrasion Value (AV), Abrasion Value Cutter Steel (AVS) and Soil Abrasion Test (SAT)



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SINTEF or Stiftelsen for Industriell og Teknisk Forskning (The Foundation for Scientific and Industrial Research), headquartered in Trondheim at the Norwegian Institute of Technology, is the largest independent research organisation in Scandinavia

NTNU or Norges Teknisk-Naturvitenskapelige Universitet (The Norwegian University of Science and Technology), also in Trondheim, is the second largest university in Norway

**Right:** Abrasion testing for determination of AV/AVS/SAT. Close-up of test piece running on prepared abrasion powder [Photo: Simon A Hagen]

SAT is a further development of the AVS test for rock samples. The SAT method has, since the introduction in 2006 [Nilsen et al, 2006,2], already been used for more than 20 different tunnelling projects, and around 200 samples have so far been tested at the NTNU/SINTEF laboratory for determination of SAT.

### Implications

The laboratory test equipment used by NTNU/SINTEF is not commercially available. The principles and details of the tests are widely published, and duplicates of equipment can be established based on this information. As mentioned, several laboratories have decided to establish such replicas for performing the suite of tests required to determine the NTNU/SINTEF drillability indices.

Experience shows that these replicas may produce results that are not comparable and consistent with the results from the NTNU/SINTEF reference laboratory. The main source of



### NTNU/SINTEF Drillability Test Method

This method is frequently used in connection with the planning and construction of major underground excavation projects. The NTNU/SINTEF laboratory has until today tested more than 3000 samples based on identical apparatus configuration through three decades. These results are compiled in a database, which constitutes a unique asset for the industry. Thus it seems fair to say that the NTNU/SINTEF laboratory is the reference laboratory for such test methods.

inconsistency is most likely related to various differences in equipment design, manufacture and installation, and in the materials used. The inconsistency in test results is also related to the fact that, although the principles of the tests may seem straightforward, the preparation, and testing itself, involve several critical steps and operations which can significantly affect the obtained results [Dahl, 2003,6].

Hence NTNU/SINTEF cannot approve the quality of tests done by other laboratories without performing extensive calibration and parallel testing. Currently NTNU/SINTEF has not established a system for such calibration testing.

The problem with obtaining comparable, reproducible and consistent test results coming from different laboratories is not unique to NTNU/SINTEF test methods. For the Cerchar Abrasiveness Index (CAI), one of the most commonly used tests to evaluate rock abrasiveness for cutter life/cost estimates of TBM projects, several studies have shown that technical factors can have a significant impact on the results [Plinninger et al, 2003,3], and that the many different approaches used at various laboratories lead to results which are not consistent and directly comparable [Rostami et al, 2005,4]. Hence, it is important for the end users of the CAI to be aware of these variations and their impact on cutter and bit cost estimates [Rostami, 2006,5].

NTNU/SINTEF frequently receive inquiries regarding the apparatus and the test method itself. Detailed information and suggested standard procedures are therefore made

available at the NTNU/SINTEF website: [www.drillability.com](http://www.drillability.com). It should however be emphasised that NTNU/SINTEF do not intend to try to approve test equipment, test procedures or test results of other laboratories. Therefore, NTNU/SINTEF can not, even when a comprehensive parallel testing program has been executed, take any responsibility or liability for the reliability and quality of test results and calculated drillability indices originating from laboratories other than the NTNU/SINTEF reference laboratory.

### Conclusions

NTNU/SINTEF is committed to ensure end users they will get quality assured and reliable drillability test results, which can be used to obtain the best possible time and cost estimates. Consistent and repetitive testing is important to ensure that all end users have confidence in these quantitative methods for describing drillability characteristics of rock and soil materials. This is the main reason for labelling the NTNU/SINTEF indices as trademarks. It is also an intention to try to avoid some of the ambiguities that may be associated with other methods, e.g. the CAI.

The NTNU/SINTEF prognosis models are along with the extensive and constantly increasing test database unique, and constitute a useful asset for cost and time estimates, risk and uncertainty analyses, classification of test results and correlation with other test methods when utilising <sup>TM</sup> labelled test results DRI<sup>TM</sup>, BWI<sup>TM</sup>, CLI<sup>TM</sup> and SAT<sup>TM</sup>. ■

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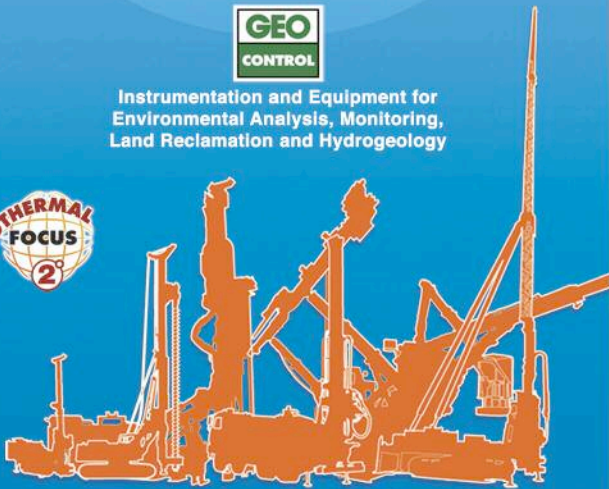
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# The Gotthard Base Tunnel and Sedrun

At the March meeting of the British Tunnelling Society Hans Bartschat and Michael Gutzeit of Bilfinger Berger's Tunnelling Division reviewed the new Gotthard Base Tunnel project, and in particular, the Sedrun section of what will be the longest transport tunnel in the world.

**T**he presentation showed the significance of the Gotthard Tunnel to and within the European rail network, as well as its historic roots. It included information about the technical conditions of the overall project including geology and the programme.

The central section (contract C360 Sedrun) of the tunnel was visited in more detail describing the technical challenges of deep mountain tunnelling with up to 2000m of overburden, reached through an 800m-deep vertical shaft, covering geology, logistics, operations, safety and the contractual framework.

## First Gotthard Tunnel

The history of the first Gotthard Tunnel underneath the Gotthard Pass, built more than 130 years ago, is one of industrialisation, political dispute, construction and social development.

In 1853 nine Swiss cantons formed the 'Gotthard-Committee', and first preliminary design work started. The Swiss engineer Wetli carried out a site survey from Erstfeld to Lugano in only five months. This is still recognised as a masterpiece in its field with regard to precision, even by today's standards. The Gotthard idea was strongly boosted by the 'Semmering-Railroad' operating in eastern Austria and the 'Mont Cenis Railroad', being under construction.

In 1861 the idea of a 15km-long 'great tunnel' underneath the Gotthard Pass was presented for the first time.

In 1871 the states of Italy, Germany and Switzerland signed an international treaty to build and operate a Gotthard rail crossing. The issued tender document for the main tunnel was noticed in Europe and even in America. The main and critical conditions of

that tender were:

- Only six weeks tender period,
- the contractor had to provide all details about methods, schedule and costs, and had to support that with substantial guarantees and bonds,
- the execution time was frighteningly short and very little was known about the geology of the Gotthard mountain.

Seven bids were submitted to the client and the contract was awarded to a Swiss company called 'Enterprise du Grand Tunnel du Gotthard' owned and managed by Louis Favre. He accepted ruinous contract conditions and guaranteed a maximum execution time of eight years.

Construction started on 13 September 1872. From the beginning the project faced immense technical difficulties, such as unstable and water-bearing rock formations. In 1875 the temperature in the tunnel rose to more than 33°C. An inadequate ventilation system complicated breathing in the tunnel filled with fumes. The original 3-shift pattern had to be reduced to five hours per shift only and the project was delayed.

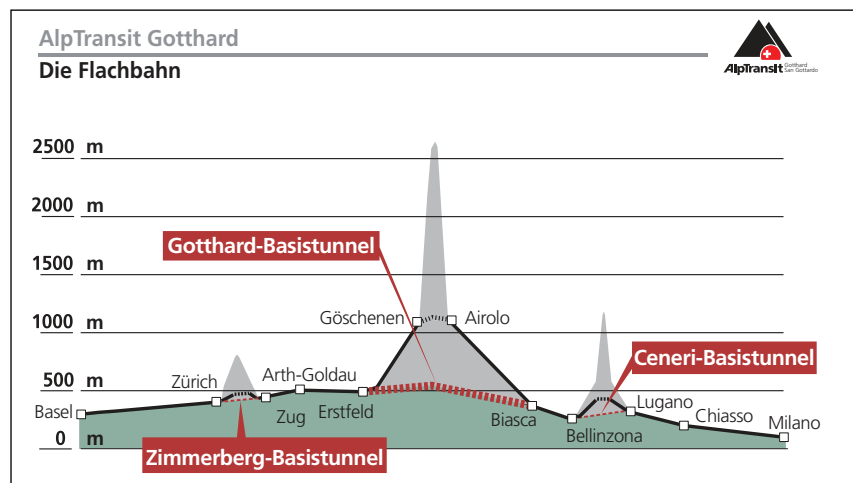
At the end of July 1872 riots broke out in the labour force and an overstrained vigilante group shot down the rioters. Four workers died and many were injured. This incident received attention all over Europe and resulted in investigations about the social and hygienic conditions of the workforce. Two Swiss agencies investigated, but even though critical conditions were found, nothing changed.

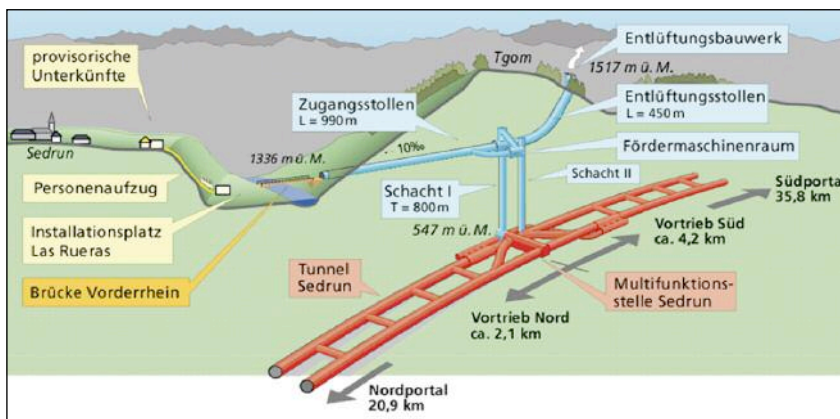
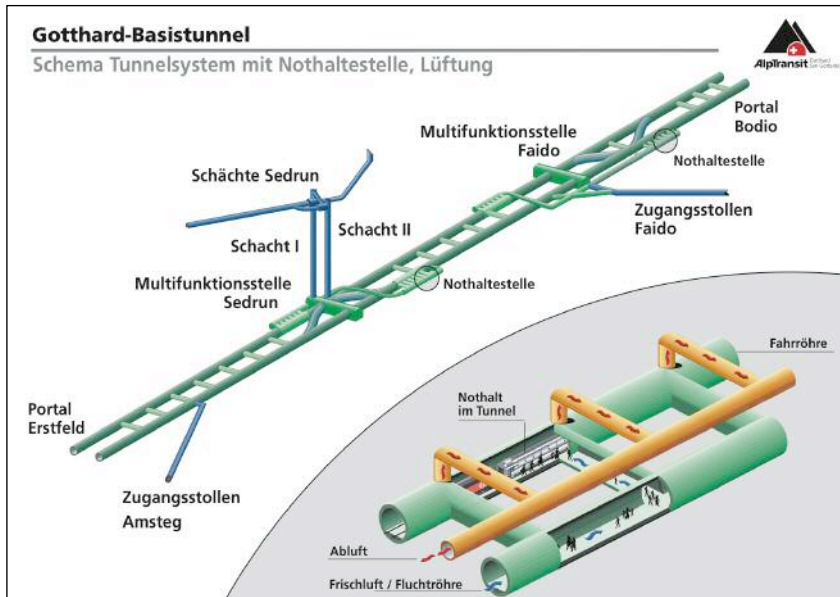
In 1876/77 new calculations showed that the original budget of CHF 187M would overrun by approximately CHF 100M. This caused a crisis that was only solved because Italy, Germany and Switzerland increased their funding following another international conference.

On 19 July 1879 Louis Favre died of a heart attack during a site visit, only 223 days before the breakthrough.

On the 29 February 1880, a Sunday, tunnel breakthrough was accomplished and on 1 June 1882 the Gotthard railway opened. The cost was CHF 227M and it took approximately 18.4 million man-days to build it, with an average of 5472 workers on site.

**Right:** Gotthard Base Tunnel project time and chainage chart





**Above, top:** Section along the route of the Gotthard Tunnel and related Zimmerberg and Ceneri base tunnels; **Above, bottom:** Schematic of the Gotthard Base Tunnel running bores and access routes

The contractor and the client ended up in court with a dispute about the final payments, and the Enterprise du Grand Tunnel du Gotthard went bankrupt. Nevertheless the Gotthard Railroad Company decided to support Louis Favre's daughter with a lifelong pension of CHF 10,000 per year to maintain her standard of living, but thousands of workers suffering from silicosis and crippling injuries were disregarded and forgotten.

### Gotthard Base Tunnel

The Gotthard base tunnel is the centrepiece of the Swiss alpine crossings. It is part of the European high-speed rail network and part of the Swiss railway upgrade scheme called 'Bahn 2000'. The high-speed European network connects cities like London, Paris, Berlin and Rome and includes the Channel Tunnel Rail Link.

Currently there are four main rail Alp transit routes:

- (1) Loetschberg Tunnel in Switzerland – operational,
- (2) Lyon – Turin route in France – under construction,
- (3) Gotthard Base Tunnel in Switzerland – under construction,
- (4) Brenner base tunnel in Austria – planned; but the Gotthard base tunnel is the most advanced high-speed alpine crossing.

Austria and Italy are working on the Brenner Base Tunnel project to relieve the current traffic congestion across the Brenner Pass, but this project has been delayed over the last decades mainly because of political and administrative disputes between Austria and Italy.

The first ideas for the Gotthard base tunnel were raised in 1947. A first preliminary project design was developed

in 1962. Approval for the preliminary design of the current tunnel was granted by the Swiss authorities in 1995.

Currently a total of about 90 million tonnes of goods cross the Alps every year. More than half is transported by road. Switzerland is already transporting about 66 per cent of their share via railroad and this will significantly grow with the new Gotthard Base Tunnel.

The tunnel is designed to both transport freight and passengers, and current planning expects that around eight million people and 40 million tonnes of freight will go through the Gotthard Tunnel by 2020. This is an average of over 200 trains a day at speeds up to 160 km/h.

Passenger trains can travel through the tunnel at up to 200 km/h. The Gotthard Base Tunnel will therefore significantly reduce current travel times across the Alps, with the travel time between Zurich and Milan for example reduced by approximately an hour or 28 per cent.

The funding split for the overall upgrade concept of the Swiss railways, 'Bahn 2000', including the Gotthard Base Tunnel comes 55 per cent from road taxes for heavy loads, 20 per cent from 0.1 per cent of Value Added Tax (VAT), 10 per cent from fuel taxation and 15 per cent from new loans. The people of Switzerland agreed to raise VAT to support the project by referendum in 1998.

The original overall programme for the Gotthard base tunnel showed a planned opening in September 2013. Current planning is to open the tunnel in 2017, but this might come forward by some months.

The Gotthard Base Tunnel is not a standalone project. The whole scheme actually consists of a chain of three major tunnels:

- The Zimmerberg Base Tunnel, 20km long on the northern approach tunnel.
- The Ceneri Base Tunnel, 15km long on the southern approach tunnel.
- The Gotthard Base Tunnel is the centrepiece, consisting of two 57km-long, single-track tunnels.

The main tunnels are connected by cross passages and have several access tunnels and shafts for emergency evacuation and ventilation. The overall scheme includes two 'Multi Functional Stations' with crossover tunnels and emergency stop facilities. The main tunnels have an outer diameter of approximately 9m and a separation of about 40m.

The client's procurement strategy was to split the project into five sections let to three different joint-venture contractors:

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**Left, top to bottom:** Schematic of the Sedrun section of the Gotthard Base Tunnel with access routes; Surface accommodation and other facilities near Sedrun; Sedrun shaft bottom with hoist cages

Amberg and Poeyry

It is a unit price contract with remeasured bill of quantities governed by Swiss law. The contract value is CHF 1.5bn (USD 1.3bn) plus about CHF 200M (USD 1.7bn) escalation to date. The contract contains a dispute resolution clause with a permanent Dispute Resolution Board (DRB) consisting of three members. An option to involve normal legal jurisdiction is given, but to make use of it would be very unusual. Usually solutions are found and agreements are reached at project level. The DRB normally only supports queries about the principle application of law or regulations.

The contract provides for fair risk sharing, such as:

- Geotechnical Baseline Report (GBR) given, with any deviation from it being at the client's risk,
- Design provided by the client with design risk remaining with the client,
- Contract dates cannot move forward, only backwards,
- Overheads and preliminaries are paid for in accordance with the actual geology.

A joint risk register is maintained at all times. It is updated by regular risk-assessment meetings with the client, the designer and relevant third parties. The main topics of this risk register are:

- Occupational Safety, Health & Environment (OHSE),
- Geological risk,
- Quality risk,
- Programme risk,
- Budget risk,
- Design risk.

The project complies with the highest international safety standards. Its site safety plan has 132 pages, is continuously updated and covers all relevant aspects of such a project. Typical OHS requirements are:

- Maximum air temperature 28°C,
- Maximum Relative Humidity 70 per cent,
- Maximum levels for all gas concentrations,
- Regular health checks for all personnel.

However this project also has some safety aspects that are not quite so common, such as:

**Avalanches:** The risk of being hit by an avalanche is continually assessed and



merger of the two biggest construction companies in Switzerland, Zschokke-Locher and Bati-Group.

### Sedrun contract C360

The Sedrun section can only be accessed through a kilometre-long, horizontal, access tunnel and an 800m-deep, vertical shaft. These features were constructed in advance in the years 1998-2001 under separate contracts.

The contract for the 6.5km-long tunnels and the multifunction station was awarded in April 2002 with an original execution time of 146 months – more than 12 years. It is noteworthy that the client awarded a 2km tunnel extension to the original contract, taking it away from the other contract, in order to optimise the overall programme. This was due to the relative actual progress between the contracts.

The site installation accommodates living quarters with single rooms for 450 people (although the maximum workforce on site was 560), workshops and warehouses, a classification and separation plant for the excavated material, and all other necessary above-ground facilities for the project. The site is located approximately 1500m above sea level, so the installations had to be designed to withstand heavy snow and freezing temperatures in winter to guarantee operations all year.

The main features of the Sedrun contract are:

- Client: Alptransit Gotthard AG
- Contractor: Transco JV (as above formed of Implenia, Bilfinger Berger, Frutiger & Pizzarotti)
- Design: Permanent design provided by the client with a design joint venture of Lombardi,



- The northern sections Erstfeld and Amsteg have been let to AGN JV (Strabag and Murer, the Swiss subsidiary of Strabag),
- The middle section Sedrun has been let to Transco JV (Implenia (Switzerland), Bilfinger Berger (Germany), Frutiger (Switzerland) and Pizzarotti (Italy), with shares of 40, 28, 18 and 14 per cent respectively)
- The southern sections Faido and Bodio have been let to TAT JV (Implenia (Switzerland), CSC (Italy), Impregilio (Italy), Hochtief (Germany) and Alpine (Austria))

Implenia is part of two different joint ventures because it is newly formed in 2006 (post contract awards) through the

monitored by trained specialists, if necessary several times a day, according to the actual weather situation. The findings and assessments are based on the avalanche risk map, which is part of the overall safety plan.

**Fire rescue:** The local fire brigade of Sedrun is too small to cope with the requirements of such a project, therefore fire rescue crews were established within the labour force of the project on a voluntary basis. They consist of:

- eight teams of four members plus one team leader, and
- one captain plus four deputies, to cover all shifts.

They have to prove and maintain their physical fitness, and have a maximum age of 40. They receive special training and professional equipment to be able to fulfil their duties safely.

The only objective of these rescue teams is to save human lives by evacuating people. Extinguishing fire is not a primary goal. In the case of a major fire the tunnel will be abandoned if all people have been evacuated.

The project has agreed a target with the client to achieve an accident rate of less than 200 reportable accidents per 1000 men-years. This might sound a lot but it must be noted that this is based on Swiss reporting rules and is actually significantly lower than the average in Swiss tunnelling. The target has been achieved and even undercut by the project to date. This has a significant positive effect on the premiums for the accident liability insurance.

The special technical challenges of this project are:

- Logistics through an 800m vertical shaft (formed by deep mining techniques),
- 2500m overburden with extreme rock temperatures and rock pressure,

- Existing civil structures (e.g. existing concrete dam),
- Tunnelling in loose rock with 800m overburden,
- Dewatering and ventilation.

Major parts of the site installation such as workshops, a concrete batching plant with a capacity of 900m<sup>3</sup> per day, a dewatering system including desanding and the pumps, transformers, etc, are located below ground in the caverns at the bottom of the access shaft. All excavated materials, building materials and equipment have to be transported by the vertical hoist.

The main hoist is a 4-rope Koepe system as is used in deep mining, with an installed power of 4.2MW. The 2-stage staggered lifting cage has a payload of 50.8 tonnes. The daily capacity of the system is 6500t/day plus 50 railcars and 960 personnel. A maximum of 40 persons can be carried in one lift. The lifting speed is 18m/s for materials and 12m/s for people.

The installed dewatering system consists of eight pumps with a total capacity of 1000 litre/s over a vertical height of 800m. This was the contractual worst case. The actual volume of water intake for all the tunnel drives was in the range of only 20 litre/s.

To service and support the tunnel drives to the south a suspended backup system was installed. This suspended unit held all necessary facilities for cooling, ventilation, dust extraction, rescue units, supply units, conveyors, etc. To move the suspended unit forward took around 4 -5 days for every 180m of tunnel drive.

The drives toward the south turned out to be normal drill-and-blast operations with advance rates of up to 9m/day. The peak performance was during the excavation of the multi-function station with eight headings at one time and 5500 linear metres of excavation in 2004.

In the north (left hand side of the geological section) the geology is governed by granite. The majority of the ground conditions towards the south are gneiss. In between the rock consists of unaltered sediments, such as dolomite and limestone, with schists untouched by the orogenesis in sandwich-type layers. Towards the north a vast shear zone was predicted composed of kikirite, which was crossed at right angles (the shortest way). Still nearly 1200m had to be excavated in this geology.

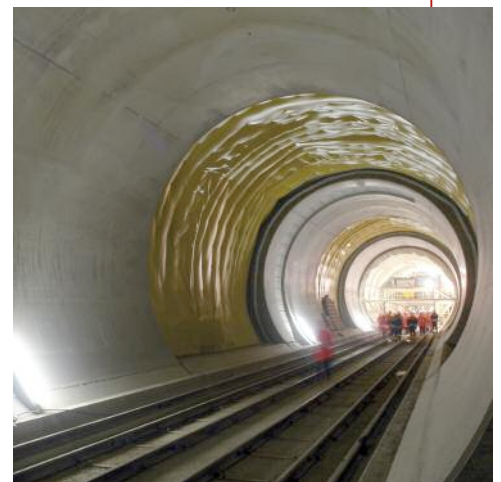
Only one site investigation from the surface was executed, as a single core, especially to investigate the area of the kikirite zone. The correlation between the drilled core and the actual findings on tunnel level was quite remarkable.

One of the biggest challenges at Sedrun was the drive through this kikirite fault zone. Radial deformations of up to 700 mm were predicted, resulting in a 2-stage support system:

- First a full-face, circular section of up to 140m<sup>2</sup> was excavated at a length of 0.6-1.0m per round, with planned overbreak of up to 700 mm to allow for the predicted deformation,
- The face was stabilised with horizontal rock bolts, 12-18m long (resulting in up to 210 m of rockbolts per metre of tunnel),
- Steel arches were placed at a minimum spacing of only 300 mm, which allowed radial deformation (up to 9.4t of steel per metre of tunnel used),

In addition radial rockbolts completed the support at this stage (290m of rockbolts per metre of tunnel).

**Below, left to right: Longitudinal geological section through Sedrun; Advancing the east bore south under steel arches and shotcrete**



At the second stage, well behind the face and after the radial movement was finished, steel-fibre-reinforced shotcrete up to 450mm thick was placed. The tunnels later received an inner lining of unreinforced in situ concrete.

The standard thickness of the concrete lining is 300mm, but up to one metre in the area of the shear zone.

Non-standard cross sections, such as the multi-function station have been steel reinforced. The tunnels are fully drained with a waterproof membrane. The design allows a water inflow of only 10g/km.

The current status is that still approximately 650m of rock has to be excavated in Sedrun with another 2200m by TBM from Faido before the final breakthrough is reached later this year.

Another 350,000m<sup>3</sup> of concrete have to be poured before the handover of the

tunnels in mid-2012 and the finishing works, such as the shaft lining and the works at the top of the shaft, will continue till 2014.

The final breakthrough for this tunnel is planned for the fourth quarter of 2010; it will then make the longest transport tunnel in the world. Even with the prospects and resources of the 21st century a project like the Gotthard Base Tunnel is at the cutting edge of technology.

#### Discussion

As is usual the Chairman invited questions on the presentation and Mike McConnell (retired, ex-Balfour Beatty) was very interested in the contract conditions used, which attempted to anticipate every eventuality on the project and develop an all-embracing bill of quantities. He wondered if this was worth the effort.

Did it cover all the conditions encountered? The speakers agreed that the design was done in great detail and considered many eventualities. In broad terms it achieved what it set out to do but inevitability with a project of this nature there will be many changes and the contract cost had risen from EUR1.2bn

(USD 1.4bn) to EUR1.6bn (USD 1.9bn).

Richard Brown wanted to know whether the tunnel was straight or curved and if curved, the minimum radius used both horizontally and vertically. The speakers were not sure of the actual figures but it was a high-speed line and was in the 15,000-16,000m range.

The concept of a passenger station at Sedrun was also queried. Had this now been cancelled or did it remain part of the scheme. Michael Gutzeit noted that this was an idea that came late in the project development, but stops on a high-speed line had a significant impact on capacity. So it was not to be included at this stage but could always be developed at a later time if the next generation decided it was necessary.

Peter Townsend (KBR) wondered how accurate the Ground Reference Conditions (GRC) proved to be. Hans Bartschat noted that, in the northern section where the ground was only investigated from the surface, the correlation was surprisingly good. To the south the geology was generally better than the GRC implied. ▀

Rapporteur: Robert Ibell

#### Acknowledgement

The authors, BTS and Tunnels & Tunnelling International thank AlpTransit Gotthard AG for permission to publish the graphics used.

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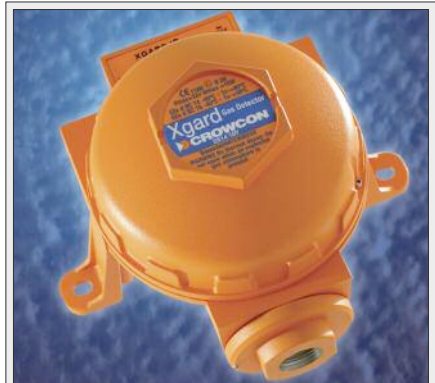
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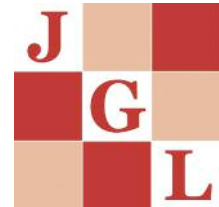
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**8-10 JUNE 2010**

**InterTunnel 2010, Turin, Italy**

Tunnelling exhibition aimed specifically at clients, contractors and consultants involved in the construction of and equipping and operation of tunnels. Contact: Mack Brooks Exhibitions; web: [www.intertunnel.com](http://www.intertunnel.com)

**9-11 JUNE 2010**

**Swiss Tunnel Congress, Lucerne, Switzerland**

Tunnelling developments in the Alps will doubtless be a talking point at the Swiss Tunnelling Society's STC. The event will be held at the KKL Lucerne. Contact: [fgu@thomibraem.ch](mailto:fgu@thomibraem.ch) web: [www.swisstunnel.ch](http://www.swisstunnel.ch)

**14-16 JUNE 2010**

**International Conference Underground Construction Prague 2010 Transport and City Tunnels**

The Czech ITA-AITES Tunnelling Association will host its 11th International Conference at the Clarion Congress Hotel Prague. Lectures will be simultaneously interpreted into English, German and Czech. Contact: Czech ITA-AITES; tel: +420 266 793 479; email: [ita-aites@metrostav.cz](mailto:ita-aites@metrostav.cz); web: [www.ita-aites.cz](http://www.ita-aites.cz)

**15-17 JUNE 2010**

**European Rock Mechanics Symposium (EUROCK 2010)**

Eurock 2010 is an ISRM Regional Symposium of Europe. The Symposium covers all the aspects of rock mechanics and rock engineering. Contact: Jean-Paul Dudt, Laboratory for Mechanics of Rock (LMR), EPFL-ENAC-LMR Station 18 CH-1015, Lausanne; tel: +41 21 693 23 25; fax: +41 21 693 41 53; email: [lmr@epfl.ch](mailto:lmr@epfl.ch); web: [www.lmr.epfl.ch](http://www.lmr.epfl.ch)

**17-18 JUNE 2010**

**50-year STUVA anniversary**

Studiengesellschaft für unterirdische Verkehrsanlagen e.V. – STUVA Mathias-Brüggen-Str. 41 D-50827 Köln Tel: +49 (0) 221 5 97 95-0 E-Mail: [info\(at\)stuva.de](mailto:info(at)stuva.de) Internet: [www.stuva.de](http://www.stuva.de)

**19-23 JUNE 2010**

**North American Tunneling Conference, Portland USA**

The 2010 NAT will be held at the Marriott Downtown Waterfront Hotel in Portland, Oregon. Conference and exhibition information and registration is available on the SME web site. Contact: Society for Mining, Metallurgy and Exploration (SME); web: [www.smenet.org](http://www.smenet.org).

**5 - 9 JULY 2010**

**BTS TUNNEL DESIGN AND CONSTRUCTION COURSE**

The BTS Course for 2010 has been modelled to address the ever changing face of the tunnelling industry and to focus on the project life from inception through to construction. tel:+44 (0)20 8774 2252 fax:+44 (0)20 8681 5706

**28 SEPTEMBER 2010**

**Tunnels and Tunnelling Conference**

T&T, in partnership with the British Tunnelling Society will be bringing you

the most important conference event of the year. With a special focus on the current and future technical developments in tunnelling construction along with a global view of tunnelling activity, the T&T conference promises to fill you in on everything you need to know heading into 2011. The conference will be held at the ICE in London. Contact: email: [conference@tunnelsonline.info](mailto:conference@tunnelsonline.info); tel: +44 (0) 20 7936 6848

**3 - 27 OCTOBER 2010**

**ISRM international Symposium 2010 and 6th Asian Rock Mechanics Symposium, New Delhi, India**

Contact: Mr. V. K. Kanjlia, Member Secretary, Indian National Group of ISRM; tel: +91-11-2611 5984/2688 2866/2410 1591; fax: +91-11-2611 6347; email: [uday@cbip.org](mailto:uday@cbip.org)/ [cbip@cbip.org](mailto:cbip@cbip.org); web: [www.arms2010.org](http://www.arms2010.org)

**23 - 26 NOVEMBER 2010**

**Bauma China 2010, Shanghai New International Expo Centre, Shanghai, China**

The Bauma trade show is famous for its German event once every three years and the China show is rapidly growing to meet its bigger brother. Contact: Messe Muenchen bauma, China Exhibition Management Messegelaende, 81823 Muenchen, Germany Tel: (+49 89) 949-20251; Fax: (+49 89) 949-20259; Email: [info@bauma-china.com](mailto:info@bauma-china.com)

**1 - 3 MARCH 2011**

**International conference and exhibition on tunnelling and trenchless technology at the Grand Dorsett Subang Hotel, Selangor, Malaysia**

The 2011 conference organised by the Tunnelling & Underground Space Technical Division (TUSTD) at The Institution of Engineers, Malaysia (IEM), will focus on tunnelling in South East Asia, future challenges and management of safety and risk. Contact: Conference Secretariat, Tunnelling and Underground Space Technical Division, The Institution of Engineers, Malaysia Bangunan Ingenieur, Lots 60/62, Jalan 62/4 P.O.Box 223 (Jalan Sultan), 46720 Petaling Jaya, Selangor, Malaysia; Tel: +(603) 7968-4001 / 4002; Fax: +(603) 7957-7678; Email: [Tunnel2011@iem.org.my](mailto:Tunnel2011@iem.org.my) Website: [www.iem.org.my](http://www.iem.org.my)

**12 - 16 SEPTEMBER 2011**

**6th International Symposium on Sprayed Concrete, Norway**

Sixth International Symposium on the modern use of wet-mix sprayed concrete for underground support will be held in Tromsø, in the north of Norway. Contact: Siri Engen The Norwegian Society of Graduate Technical and Scientific Professionals - Tekna; fax: +47 22 94 75 01

## BRITISH TUNNELLING SOCIETY

**17 JUNE 2010: Atlantic Sea Tunnels in Norway**

Prof. Eivind Grov, vice president ITA and president of the Norwegian Tunnelling Society will speak on road tunnels and bridges being built along Norway's western sea coast. ICE, 5.30pm for 6pm start.

**16 SEPTEMBER 2010: Tunnelling in Seattle - Past, Present and Future**

How tunnels have been used in Seattle and why they are now starting to push the envelope in American tunnelling. The talk will look in detail at recent projects, particularly Brightwater, and at the planned 58ft diameter bore for the Alaskan Way viaduct replacement tunnel.

Brightwater is a \$2 billion new wastewater treatment system, which includes 14 miles of soft-ground bored tunnel. Currently under construction, the tunnels are being bored using 2 EPB and 2 slurry TBMs, and are notable for their long drives and high mining pressures. ICE, 5.30pm for 6pm start.

**21 OCTOBER 2010: Sir Alan Muir Wood Memorial Symposium**

The British Tunnelling Society is presenting a symposium on tunnelling and geotechnical themes with papers looking at recent tunnelling case histories, risk, and the inter-relationship of current design and research. Confirmed speakers include, prof Robert Mair, Prof John Burland, Prof David Muir Wood, Robert Muir Wood, prof Paul Jowitt and Martin Knights. Contact: [bts@event-logistics.co.uk](mailto:bts@event-logistics.co.uk)

**18 NOVEMBER 2010: Pittsburgh Northshore Connector**

Stephen Woodrow and Andy Miller of Faber Maunsell (AECOM) will deliver this talk on the light rail tunnels in mixed ground conditions with challenging vertical alignment.

The tunnelling works for the Northshore Connector Project in Pittsburgh, USA, involved several engineering challenges. The construction included 6.5m i.d. bore tunnels, 660m long passing under the Allegheny River. ICE, 5.30pm for 6pm start.

**16 DECEMBER 2010: Baggage tunnel design and construction at Heathrow Airport**

Andrew Stephenson of BAA, Enrique Blanco of Ferrovial and Athur Darby of Mott MacDonald give details on the challenges of constructing the tunnel under one of the world's busiest airports. ICE, 5.30pm for 6pm start.

## 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: Editor, 'Tunnels & Tunnelling International', John Carpenter House, 7 Carmelite Street, London, EC4Y 0BS, United Kingdom.

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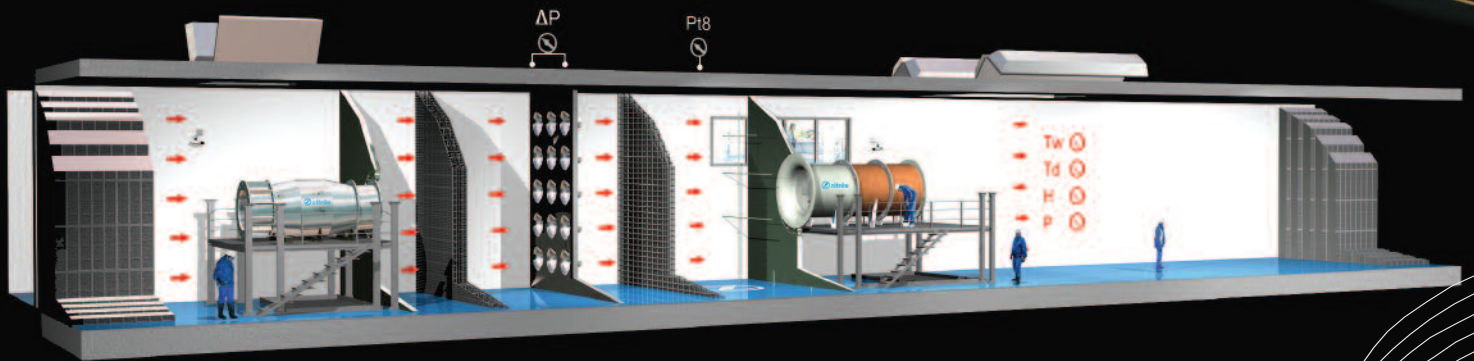
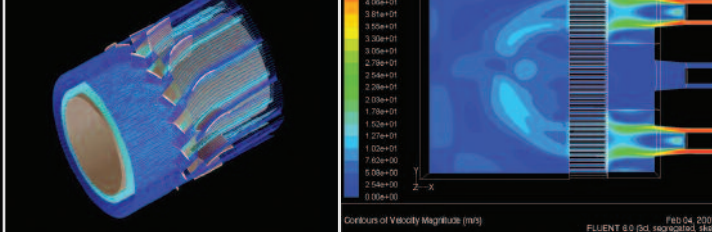
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