

OCTOBER 2010

tunnels & tunnelling INTERNATIONAL



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Special report: Southern Europe

T&TI journeys to Turkey, Spain and Italy to see how work is progressing

Technical: Tunnel user safety and rescue

T&TI looks at the systems that keep tunnel users safe and goes in depth on water mist

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Cutting the Bilbao metro

Construction has started on Bilbao's new metro line 3 to link with the city's airport. T&TI pays a visit



PUSHING THE LIMITS: OUTSTANDING SUCCESS IN HALLANDSÅS.

High mountain water pressures and inflow quantities, extremely heterogeneous geological conditions and blocky rock are characterizing one of the most difficult tunnel projects in the world: the two-tube Hallandsås railway tunnel in Sweden. The joint venture between Skanska and Vinci is rising to this extreme challenge using technology made by Herrenknecht. The convertible Mixshield S-246 (Ø 10.53m) can cope with mountain water pressures of up to 13bar and is capable of operating in both the open hard rock mode and the closed mode with slurry support.

Applying patience and specialist knowhow, the appropriate tunnelling mode was chosen in close and focused cooperation among all of the parties involved in the project, necessitating coordinated changes between the operation modes as well as efficiently adapted working cycles (drilling stroke, lining, exploration and injection drillings) which meet the strict environmental protection requirements.

The tunnelling teams proudly celebrated breakthrough at the eastern tube on August 25, 2010. The best weekly performance was 94.6m. Stretching the limits of what is possible in tunnelling has slowly but steadily been extended in Sweden. Herrenknecht congratulates everyone involved in the project on this impressive success and wishes the best of luck for the second tunnel!

FÖRSLÖV | SWEDEN

PROJECT DATA



**S-246, Mixshield
(convertible)**
Diameter: 10,530mm
Installed power: 4,000kW
Tunnel length: 2x 5,480m
Geology: gneiss, amphibolite,
diabase

CONTRACTOR

Skanska Sweden AB,
Vinci Construction
Grands Projets





comment

Will we, won't we?

For the past couple of years, since cheap credit ended, governments around the world have been in a state of flux. This time last year, the tunnelling industry was welcoming stimulus packages in the US, cross party backing for major projects in the UK and bailouts and capital injections across Europe.

Major infrastructure projects were breaking ground as the government emptied the coffers into the construction sector in an effort to replicate the success of Franklin D Roosevelt's New Deal following the Wall Street crash of the late 1920s.

It wasn't all rose coloured. Smaller projects were shelved; local governments struggled to find financing for city developments. But there was hope that the national government spending splurge would fill the hole left by the failing projects and perhaps go beyond that.

But just one year later, the sure-footed projects are suddenly finding the ground crumbling beneath them as world leaders wonder whether a spending spree is the best way to counter a decade of overspend.

October is very much a month of cuts. The first to fall, right as *T&T* was going to press, was the USD 8.7bn Access to the Regions Core (ARC or Trans-Hudson Express) project. The tunnel had received a chunk of funding, some USD 3bn, from President Barack Obama's stimulus package. But with cost prediction spiralling to USD 11bn or even USD 14bn, the project was pulled (see page 5).

The 30-day suspension and then cancellation of ARC is reflective of a wider US trend of republicans voicing opposition to rail plans, in the run up to midterm elections on 2 November. Polls indicate enough Republicans are likely to defeat their Democrat opponents to take control of the House and rail projects nationwide could be in jeopardy as the 'Party of No' takes a hard-line stance on government spending.

Separately, members of the Republican party announced their 'Pledge to America' for the midterm election, which calls for limiting government spending, including the investments in infrastructure as part of the 2009 Recovery Act passed by Congress. It reads: "Congress should move immediately to cancel unspent 'stimulus' funds, and block any attempts to extend the timeline for spending 'stimulus' funds."

It's a similar story in Austria, where the Ministry of Transport is reviewing large infrastructure projects, including rail investments and, notably, the Brenner Base Tunnel. The evaluation is scheduled to end in mid-October, which is when the tunnel project hopes to move forward to tendering contracts.

While the review hasn't caused panic, it has caused delays. The organisation in charge of Brenner Base Tunnel's delivery, BBT, has said it will slow down planned works for 2011 and 2012 in attempts to help out the ministry and remains confident the project won't be affected.

In the UK the treasury is in the final stages of the Comprehensive Spending Review. Ahead of the review, Crossrail announced it would be delaying the award of the running tunnel contracts. This sparked fears that the project may face cuts.

The second high speed line, HS2, proposed for the UK could also suffer under the review. But some hope can be held in the line from London to Leeds and Manchester gaining the backing of transport minister Philip Hammond.

The odds are stacked against the industry over the coming months.

Jon Young and Nicole Robinson



On the cover

Construction has kicked off on Bilbao metro line 3. *T&T* went to northern Spain to see the roadheaders in action



On the back

The Himalayan mountain range is home to some of the toughest tunnelling sites. *T&T Asia* catches up with some of the work



In the supplement

Before a TBM can start boring first it has to get to site. *T&T Logistics* reviews the shipping channels

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Trans-Hudson Express pulled

USA

New Jersey governor Chris Christie ended the USD 8.7bn ARC (Access to the Region's Core) tunnel, also known as the Trans-Hudson Express Tunnel, after the 30-day suspension he called in mid-September.

At a press conference Christie said the state couldn't risk the rail tunnel costing more than had been originally planned because the budget could increase to USD 11bn, or even USD 14bn.

"We simply can't spend what we don't have," he said. "I had to figure out how I was going to pay for it.

We simply can't."

The project called for two single-track rail lines connecting New Jersey to Penn Station in Manhattan beneath the Hudson River, in three sections. A contract for the 2.26km Hudson Tunnels had not yet been awarded, though five contractors had been pre-qualified.

Contracts for tunnels on the New Jersey and Manhattan lengths have been awarded. A USD 583M contract went to Barnard-Judlau JV for the 1.6km long Manhattan Tunnels. A Shea, Schiavone and Skanska JV received a USD 259M contract for the two 1.6km TBM bored Palisades Tunnels on the New Jersey side of the river.

Approximately USD 3bn had been set aside for funding from both the Federal Government and the Port Authority.

Christie, a republican, has been

called on by New Jersey democrats during the suspension to push the tunnel project forward, noting that killing it would cost jobs and billions of dollars slated for New Jersey.

Senator Frank Lautenberg (D-N.J.), who was a member of the Senate Transportation Appropriations Subcommittee, called the decision one of the biggest public policy blunders in the state's history.

"It could take New Jersey another 30 to 40 years and a much higher price tag to recover from the loss of the ARC Tunnel," he said.

He has accused Christie of using outdated numbers when saying the cost could reach USD 14bn. "After meetings between engineers from NJ Transit and the FTA in recent weeks, the final cost of the project would have been below USD11 billion," Lautenberg said.

Gotthard sees breakthrough

SWITZERLAND-AUSTRIA

A breakthrough at the 57km Gotthard Base Tunnel is scheduled for October 15 between subsections Sedrun and Faido.

At the Sedrun segment, additional exploration of the rock under the breakthrough area took place this summer as a core bore with a length of more than 220m was driven west from a niche in the south drive. Except for relatively short lengths, constructor AlpTransit Gotthard found the bore indicated good geological conditions.

As of 1 October, 98.2 per cent of the tunnels, shafts and passages have been excavated. Roughly 38km on both the west

and east tubes have completed linings and are ready for railway technology to be installed.

On the Faido side of the breakthrough, both of the TBMs working in the west and east tubes had overhaul work carried out this summer. Following that, in the east, the TBM had an average daily advance rate in August of around 16.3m. To the west, the TBM was still in the area of reverse drive and the average daily advance rate was around 8.8m. By the end of the month the TBM had cut through that area and normal operation rates had returned.

Completion of the USD 9bn project is expected for 2017 and it will be the longest road or railway tunnel in the world.

News in brief

Yas Tunnel opens

Abu Dhabi's Yas Tunnel officially opened this month. The 1.1km tunnel is 43m wide with a 4.5m height clearance, and constructed by Taisei. With six traffic lanes, it connects Al Raha Beach to Yas Island.

Busy holiday season this summer for Channel Tunnel

Eurotunnel announced last month it had a "significant increase" in holiday traffic this summer, with 533,238 cars and other vehicles carried on passenger shuttles between 01 July and 31 August, up by 17 per cent compared to the same time last year.

Below: A Sedrun and Faido breakthrough is expected in October



Caracas Tunnelling starts

VENEZUELA

TBMs started excavation work on the final portions of the 7.5km Line 5 for the Caracas Metro in Venezuela, late last month.

Two EPB Shield machines from Herrenknecht are driving two 4km long parallel tunnels with segmental lining that will each have a one-track subway operation. Once completed, Line 5 will have six new stations, built by NATM and will run between existing Plaza Venezuela Station and new Miranda II Station.

Contractor Odebrecht Venezuela assembled the 5.6m diameter machines inside

trenches measuring more than 26m to construct the first 3km of the line. These runs finished this summer when the second machine arrived at La Macarena shaft where they are in the process of starting the parallel tunnels.

The USD 1.1bn project will connect the western and eastern sides of Caracas. Currently the city's metro network has four lines and serves a daily demand of approximately 1,700,000 people. Population growth has resulted in saturation of the system and the Metro de Caracas is developing several expansion plans with the help of government aid.

Devil's Slide breaks through

USA

The Devil's Slide tunnel project in California saw a breakthrough early this month at



the northern end of the tunnel. A breakthrough on the southern side of the tunnel is scheduled for a few weeks' time.

Kiewit won the contract in November 2006 to build two tunnels beneath San Pedro Mountain, each 30ft (9.1m) wide and 4,200ft (1280m) long, in November 2006 and has been employing a mixture of drill-and-blast and roadheader excavation for the tunnel.

Running between Pacifica and

Left: Roadheader excavation broke through earlier this month

Montara, Route 1 hugs the coastline and at one point the road crosses the Devil's Slide, a region of steep, unstable geological formation.

This section of road has a long history of closure due to rockslides and land slippage. One of the longest road closures happened in 1995. It lasted 158 days, and cost almost USD 3M to repair.

Following many years of public input it was decided Devil's Slide would be bypassed by two inland tunnels.

The tunnel opening is planned for 2011.

Brightwater begins final excavations

USA

Construction resumed 1 October on the final section of the 13mi (20.9km) Brightwater conveyance pipeline in Washington, following the project's 2009 suspension due to TBM damage.

Contractor Jay Dee/Coluccio (JDC) joint venture put its newly rebuilt Lovat TBM back into action to complete construction on the remaining 1.9mi (3.1km) segment of the 4mi (6.4km) BT-3 tunnel.

Client King County hired JDC last spring to construct the section, replacing the Vinci/Parsons/Frontier-Kemper joint venture, which was originally working on the project with two

Herrenknecht TBMs. Both machines were damaged after a few months of operation and were shutdown in 2009.

In February, King County executive Dow Constantine determined that completing the tunnel with one of the damaged machines would likely result in unacceptable cost overruns and project delays. That TBM remains idled about 300ft (91.4 m) below ground in Lake Forest Park. It will be disassembled and removed through the North Kenmore portal.

The other damaged TBM was repaired and it successfully completed excavation from Kenmore to Bothwell for the 2.2mi (3.5km) BT-2 tunnel in June.

JDC completed the 4mi

eastbound BT-4 tunnel in June, which is adjoining to final section, BT-3. This put JDC in a good position to pick up work on BT-3, using the existing machine, according to King County.

"We're off to a good start with our final push to get the Brightwater tunnel completed," said Gunars Sreibers, Brightwater project manager with King County's Wastewater Treatment Division. "It's a complex project and we're very confident in the contractor's ability to get the job done so we can get the Brightwater tunnel in service in 2012."

The Vinci/Parsons/Frontier-Kemp joint venture remains under contract with King County to complete the final lining in the BT-3 tunnel.

Transcity wins Brisbane tunnel contract

AUSTRALIA

The Transcity consortium led by Spanish construction company Acciona has won the ASD 1.5bn (USD 1.5bn) contract to construct the Northern Link Tunnel in Brisbane, Australia.

The Northern Link Tunnel

consists of two parallel tunnels, 12m in diameter and approximately 4.3km long that will join the Centenary Motorway with the Inner City Bypass. Two TBMs will be employed to construct the tunnels, which will run below the ground at a depth of up to 40m

Brisbane City Council chose Transcity—also formed of Ghella and BMD Constructions—to design, construct, operate and maintain the Northern Link Tunnel project for 10 years.

Work will begin in December and the tunnel will be operational by 2014.

News in brief

India sets aside funds for future rail developments

The Indian Government has allocated INR170,000M (USD 3.84bn) to develop a rail network connecting eight cities in the northeast of the country by 2016.

Toulouse tunneling

Tenders for a 1066m tunnel and other underground works such as escape and ventilation passages are invited for the Saint-Béat tunnel around Saint-Béat Arlos on the RN125 highway in the Midi-Pyrénées of France. Further information from, and tenders are due by 29 November to DREAL Midi-Pyrénées CSM/CPAR in Toulouse.

Beijing metro NFM TBMs

Early last month two 6.28m diameter EPB TBMs from NFM were ready to start excavation on line 10 of the Beijing Metro, China. They have been assembled and tested on site in the south of the city. Other NFM Technologies EPB TBMs have achieved good progress on metro line 5, with 250 m covered in one week. A similar TBM completed the excavation of the first tube on line 8 under good conditions.

Void material safe

BASF is relaunching its Meyco MP 367 foam to the US mining industry for rapid filling of closed voids and cavities following a completion of a review into its use. There was earlier concern, including MSHA involvement, when a fire broke out whilst the material was being tested in March for large volume, remote emergency mine sealing – something that is not a use recommended by Meyco BASF. The fire was not due to the material and there is now full confidence in the material if used according to the Meyco's technical data sheet.

Lee tunnel construction starts

GREAT BRITAIN

Ground was broken late last month on the Lee Tunnel, a new four-mile 7m i.d. sewer, which will prevent 16M tonnes of sewage overflowing into the River Lee each year.

The GBP 635M (USD 1bn) tunnel will take discharges from London's largest combined sewer overflow at Abbey Mills in Stratford, east London, for treatment at Beckton sewage works, which is being expanded so it can deal with the additional flows.

The Lee Tunnel will help prevent 40 per cent of the 39M tonnes on average of sewage that enters the River Thames and River Lee each year from 57 overflow points.

Main contractor, the MBV joint venture of Morgan Sindall, VINCI Construction Grands Projets and Bachy Soletanche, started construction last month on one of four shafts, which will be up to 75m deep. Tunnelling work will start in 2012, with the project due for completion in 2014.

The Lee Tunnel will be the deepest tunnel ever constructed in London, and is Thames Water's biggest engineering project to date.



Thames Tunnel out for public consultation

GREAT BRITAIN

Thames Water launched a 14-week public consultation last month on plans for the proposed Thames Tunnel, which will significantly reduce sewage discharges into the River Thames.

The 7.2m i.d. tunnel will run up to 32km from its starting point in west London and will broadly follow the route of the river at a depth of 30m to 75m, to the east of Tower Bridge before going one of three ways:

- North east to connect to the Lee Tunnel at Abbey Mills in Stratford - the shortest of the proposed routes;
- East following the river and crossing the Greenwich peninsular up to Beckton Sewage Works in Newham;
- Or south east, straight to Greenwich and then on to Beckton

Public exhibitions are being held across London from 27 September until 22 October 2010.

Thames Water will review the feedback ahead of the second phase of public consultation in 2011. The target date for the submission of the planning application is mid 2012.

Y-shape for HS2 is preferred option

GREAT BRITAIN

The UK Government has confirmed it will pursue the 'Y-shaped' option for the high-speed rail network linking London to Birmingham. This will consist of two separate corridors, one to Manchester, and the other to the East Midlands and South Yorkshire.

Transport secretary Philip Hammond said in a new remit letter for HS2—the company set up by the government to consider

the case for the new high speed rail services—that "it is clear the 'Y-shape' would offer a range and quantum of benefit that the 'reverse S' is unlikely to match."

HS2's assessment found that the 'Y-shaped' option is projected to generate GBP 10bn (USD 15bn) more in revenues than the alternative 'reverse S' option.

HS2 will now develop route proposals for two separate legs from Birmingham to Manchester and to Leeds. Though no final

decision on whether the project goes ahead will be made until a full public consultation, due to start in 2011, has been carried out.

"Subject to the outcome of the public consultation next year...the secretary of state has asked us to deliver our report on our findings by December 2011," said Brian Briscoe, chairman of HS2.

"There would then be a further consultation on the line of route from Birmingham to Leeds and Manchester."

News in brief

■ New CFO for CH2M Hill

Michael Lucki has been named senior vice president and CFO of CH2M Hill as of 1 November. He joins the Denver-based engineering, construction and operations firm from Ernst & Young LLP where he was previously a partner, leading the global engineering and construction industry practice since 1994, and the global infrastructure practice since 2008.

Toronto Mayoral candidate proposes express tunnel

CANADA

Election fever has turned to tunnelling in Toronto. Mayoral candidate Rocco Rossi has called for an extension of the Allen expressway to the downtown core by means of a tunnel.

"Welcome to the Toronto Tunnel," said Rossi, committing to having "shovels in the ground" by the end of his first term as Mayor. "This intersection is where vision

meets opportunity," said Rossi standing at the foot of the Allen expressway and Eglinton Avenue West. "Under my plan, we will tunnel the Eglinton subway crosstown and we will tunnel the Allen expressway downtown."

Rossi said that cities in Switzerland, Australia, Japan and the United States have all completed or have commenced underground transportation projects. "The technology is better

than ever," he added.

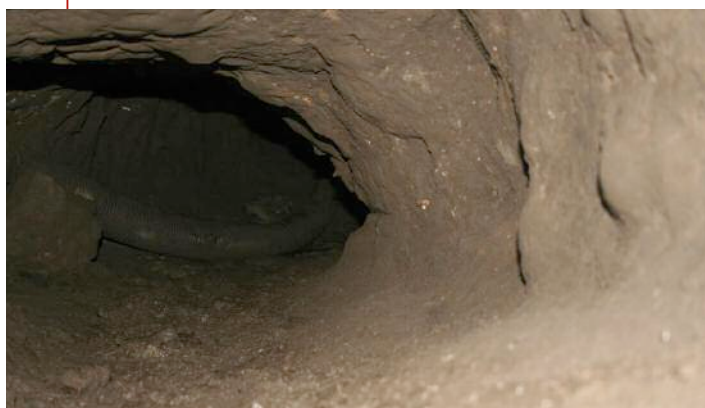
Rossi noted that Toronto has the worst commute times in North America. "There's no quality of life for the drivers lined up here," said Rossi, "or for the in the nearby streets inhaling exhaust fumes from the idling cars."

Rossi said that the project would be funded through a public-private-partnership so that "Torontonians will be able to drive the Toronto Tunnel without driving

the city into debt."

Rossi's office said, "A determination of an exact cost estimate will require an engineering report. However, similar projects in Switzerland, Australia, Los Angeles, Seattle, Nanjing and some underway like in Miami suggest that the cost can be as little as USD 105 million per kilometre. Keeping costs down will require new accountability measures at City Hall."

One tunnel leads to another



USA

Border patrol agents discovered an illicit tunnel connected to a storm drain east of the DeConcini Port of Entry, near Nogales, Arizona, on the border with Mexico.

The U.S. Customs and Border Protection Agency had seized 665lb (302kg) of marijuana and later determined it had been smuggled in through a tunnel. While investigating this, the agents entered the storm drain and found the second tunnel, which originated in Mexico and runs parallel to the drainage system.

Plans to remediate the tunnel,

which is said to measure 2ft (0.61m) by 2ft and run for 50ft under the border, are underway.

The agency highlighted that the above ground work of border patrol agents makes it difficult for smugglers to move contraband into the U.S. Interim patrol agent in charge, Carla Provost, said "tunnels are a third party indicator of the Border Patrol's effectiveness because agents are forcing smuggling organisations to change their operations."

In the 2009 fiscal year, U.S. Border Patrol discovered 20 illicit tunnels in the Tucson, Arizona, sector. This most recent discovery brings the 2010 total up to seven.

China orders TBM

CHINA

At up to 60m below the water level, a new subsea tunnel in southern China promises to ramp up the nation's steel output. Robbins will supply a 6.26m diameter Slurry TBM to excavate the 2.7km long Zhanjiang Bay Cross-Sea Tunnel.

The tunnel is part of a larger fresh water transfer project that will draw from the nearby Jianjiang River to supply a new steel plant on Dong Hai Island. The tunnel will travel beneath the bay with up to 22m of overburden.

The supply of the machine is a full cooperation between Mitsubishi Heavy Industries Mechatronics Systems and The Robbins Company. Robbins will supply components in China, assembly, and local support throughout excavation, while MHI-MS will provide key components and engineering expertise for the Slurry TBM and back-up system. The machine will be assembled in the Robbins Shanghai manufacturing facility.

The TBM will be delivered to the jobsite in March 2011. "Robbins fully expects that its entry into the Slurry TBM market will gain quick acceptance, as has been the case with our entry into the soft ground

EPB market," said Lok Home, Robbins President.

The high-powered machine features 20 thrust cylinders for a total thrust of 46,000 kN—a feature needed due to the 6 bar water pressure in the bay. A mixed ground cutterhead with hard facing will be fitted with interchangeable knife-edge bits and disc cutters for geology including coarse to abrasive sand, gravel and silt.

To effectively remove the water-bearing ground, a large slurry chamber will combine the muck and bentonite while applying even pressure through the mud screen across the face. Two probe drills, mounted on spherical joints for increased range of motion, will probe ahead and pre-grout depending on the geology and need for intervention.

As the machine bores, it will line the tunnel with 450mm thick reinforced concrete segments in a 5+1 arrangement. Active articulation will be used in curves down to a 200m radius, in order to prevent segment deformation.

Once complete in 2011, twin pipelines will provide fresh water to the Guangdong Steel Plant. The water supply project is part of a plan by the Chinese government to improve the quality and output of steel in Guangdong Province.



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From ponies to performance

REFURBISHMENT

In the afternoon conference, delegates were themselves renewed by a presentation on major refurbishment of one of the oldest tunnels in daily, the 1.4km-long northbound bore of London's Blackwall Tunnel. Graham Carter of Transport for London (TfL) and Nick Tucker of Mott MacDonald explained how the tunnel now has to cope with traffic and other conditions that could not be imagined when it was opened in 1897 to around 1000 horse and carriages a day. Now it handles 50,000 vehicles a day, including heavy freight, as a main route under the River Thames.

The northbound bore was refurbished in the 1960s and again in 1992, but since then demands for better safety standards and updating of existing services necessitated another major refit. But Tucker explained that there was, literally,



little room for manoeuvre due to the small section of the tunnel structure, sharp bends and daily traffic demands (including vehicle overheight and breakdown incidents), so the project called for a great deal of imagination. The structure ruled out existing routes and emergency lanes, but the lining was improved by milling back to steel and reapplying a thinner lining with better resistance to vehicle strikes. To the same end there are now new carriageway kerbs on the sharp bends.

The work included reroofing of the four ventilations shafts over new purpose-built reversible fans (four per shaft) for smoke control

in case of fire. Other improved safety measures installed include better communications with CCTV image analysis, public address and vehicle radio rebroadcasting, as well as improved incident detection for smoke, halted and overheight vehicles, shed loads and other unusual incidents, plus modern lighting.

Innovation and imagination also extended to working periods, but with complete bore closures restricted to weekends and night-time possessions, with traffic using the other bore and alternative river crossings. Surface construction work was banned at weekends in consideration of neighbours. Nevertheless the schedule has been accelerated, and the end of this success story in overcoming numerous difficulties will now come six months earlier than the December 2012 deadline for completion by contractor BAM Nuttall.

News in brief

Robbins chief advises on coping with rock bursting

Robbins president Lok Home told delegates the key to managing rock bursting was prediction and prevention. He said "rock bursting should be detected in advance and de-stressed in advance of boring." He added that the rock failure cannot be prevented and the supports should be designed to flex to relieve overstress at the surface.

Northern Line Extension to Battersea hangs on planning

Speaking before his presentation David McCann said the Northern Line Extension to Battersea will only go ahead if the local council approve some three million square metres or development on the Battersea site. Less than that and the underground line is not viable.

Research programme looking for contractors

Tunconstruct is calling for contractors to apply for the next phase of funding as part of its multi-disciplinary research project to promote development and implementation of technological innovation in underground construction in Europe.

The programme has been set up to contribute to an increased quality of life for Europeans by reducing construction time and cost of planned and future underground infrastructures.

Phase 2 focuses on technology, developing TBMs, roadheaders, shotcreting, materials and ways to improve environmental impact and worker safety.

The previous consortium comprised 33 partners and seven clients from countries across Europe and had a budget of EUR 26M (USD 35.7M) for four years from 2005 to 2009.

Gernot Beer, professor at Graz University of Technology, Austria and the coordinator for Tunconstruct said for this phase the project is looking for very innovative opportunities and particularly for participation from larger, well-known companies in Europe.

In the previous consortium there was heavy participation from Spanish companies, he said. Though with the recession taking a toll on the construction industry, it is expected there will be a wider spread across Europe.

The project is co-financed by the European Commission, under its 6th framework program, which provides 54 per cent of the EUR 26M quadrennial budget.

Further information and contact details are available at www.tunconstruct.org.

Network Rail unveils cut-price plan for UK rail tunnels

Network Rail and structural engineer specialist Donaldson Associates have unveiled detailed design ideas of how tunnels in the UK should be renewed and repaired over the next decade.

Speaking at Tunnels & Tunnelling International's 2010 conference, the organisations presented drawings from their new technical user manuals that will be used by contractors and designers on future maintenance projects.

The new user manuals outline description of methods, limitations, defects, how materials and methods should be tested, and health and safety best practices.

With the new standards, Network Rail hopes to reduce design costs by eliminating repetitive design, improve productivity, minimise contractor and subcontractor costs and minimise future maintenance requirements.

Donaldson Associates chief civil engineer Peter Harris said, "standard maintenance drawings were released two years ago but now we have much larger areas that are in need of repair, which require more efficient and complex design plans."

Standard renewal methods, which Network Rail hope to implement include the spraying of concrete linings and shaft lining to prevent weathering of brickwork.

"On our Seven Oaks project, 75m of brickwork was weathered by water so we came up with the idea of implementing a glass reinforced liner into the shaft rather than replacing all of the damaged brickwork. This is a safer and less costly solution," said Harris.

More than 60 per cent of the European tunnelling industry's work load is expected to come from refurbishment projects over the next ten years.

Tam and Normet buy Indian arm

ACQUISITION

The Tam International Group and Normet Group announced they have acquired 100 per cent of the share capital of "Tam Construction Chemicals (India)". Previously TAM India was a 50/50 joint venture with Sharat Nath. Nath will continue as a

director of the company, responsible for sales acquisition.

The decision to acquire the remaining shares is part of Tam and Normet's global expansion strategy which was formally announced in April 2010. Normet, which manufactures specialist equipment for large construction projects already has a strong

presence in India and the addition of Tam's Construction Chemicals will allow them to develop in the construction sector.

Tom Melbye, president of Normet Group and executive Chairman of Tam Group, said "India is one of the fastest growing markets for construction equipment and related

chemicals and the amount of Infrastructure projects planned over the next few years is simply staggering. Normet and Tam are committed to serving our valued customers and the acquisition of 100 per cent of the business shows our long term commitment and confidence in the Indian market"

News in brief

▼ Brenner study contract

The Brenner base tunnel developer (BBT) has issued an invitation to tender for geotechnical deformation measurements and control instrumentation for the Ampass access adit and Wolf 1 zones. The contract value is EUR400 000 excluding vat and duration 17 months. Documents must be requested by 3 November from Dr Johann Hager at Galleria di Base del Brennero Brenner Basistunnel BBT SE in Innsbruck on email ava@bbt-se.com or tel.: +43 512 403 0110, and returned by 10 November.

▼ Yamali II hydro Turkey

Enerjisa Enerji Üretim has issued an invitation to tender for a public contract to construct the Yamanli II Weir and hydropower project located on the Göksu River in the Adana and Kahramanmaraş provinces of Turkey. The works include a 3.5m id headrace (energy) tunnel of 14.8km. Tenders deadline is 1 November and requests for documents must be received by 28 October. Further information from and tenders to Melih Karadut at the client in Blagat, Ankara on email mkaradut@enerjisa.com.tr or tel +90 312583 4067, fax +90 312 473 8546.

Top tunnellers 'knighted'

AWARDS OR COMPANY

Sandvik Construction & Mining held a special 'knighting' ceremony of top roadheader customers in Bilbao, Spain, last month at a customer and media event marking the launch of its Sandvik MT520 roadheader working on the new Line 3 of the Bilbao Metro (see main article this issue).

In a 'recently revived tradition' new 'knights' were selected on the basis of the number of Sandvik roadheaders they had purchased in the year and, of course, working them efficiently. Carrying out the awards of 'Tunnel Knighthoods' with a steady hand and fortunately blunt 'sword' was Duncan McGregor, vice-president of construction products of Sandvik

Mining & Construction.

The new Tunnel Knights are:

- Jose Luis Duarte Penido of J Dantas Engenharia, Brazil;
- Chris Moore of John Holland Tunnelling, Australia;
- Arun Karambelkar of Hindustan Construction, India;
- Paul Liceaga of Construcciones Muria, Spain;
- Jose Heli Almeida of Toniolo Busnello, Brazil.

Central Subway holds conference for tunnelling contract

USA

The San Francisco Municipal Transportation Agency held a conference late last month to provide information about the upcoming tunnelling station, trackwork and systems contracts for the city's Central Subway Project.

Jointly held with the Laborers'

International Union of North America, the Prime Contractor Tunneling conference saw contractors attending from all over the world with the opportunity to network and develop relationships to form teams in preparation for bid submittals early next year.

The USD 1.58bn project includes the USD 195M contract

1252 for tunnelling 1.7miles (2.7km) of twin bore tunnels, on which construction is expected to start in Q2 2011. Three separate contracts for Union Square/Market Street Station, Chinatown Station and Moscone Station will be advertised in late 2011/early 2012, with construction starting in 2012.

RTA meeting discusses Sochi

RUSSIA

A consultative meeting of the Scientific and Technical Council of the Russian Tunnel Association recently discussed the guidelines for rock treatment produced by Tunnel Detachment 44. This was with reference to primary and permanent lining of

tunnel inverts in the Prospect Mountain Resort near Sochi in the Caucasus. Here the 2014 Winter Olympics are scheduled for which major infrastructure development is under way.

The meeting studied tunnel design for tunnels numbered 1 and 2 for compliance with construction codes and regulations regarding

the primary lining, including the associated drainage and emergency exit galleries.

The work affects 172km of federal road M-27 Dzhugba to Sochi bypass

Interested parties in protocol and expert opinion were invited to contact Tunnel Detachment 44 of the Federal Road Agency 'Black Sea'.

Raise borer tries to free trapped miners

CHILEAN MINERS

Rescue workers trying to free 33 trapped miners in the San Jose Mine near the town Copiapo in the north of Chile, have pinned their hopes on a raise borer drilling the 688m. As T&TI went to press, the bore rig had reached 587m on the pilot drive.

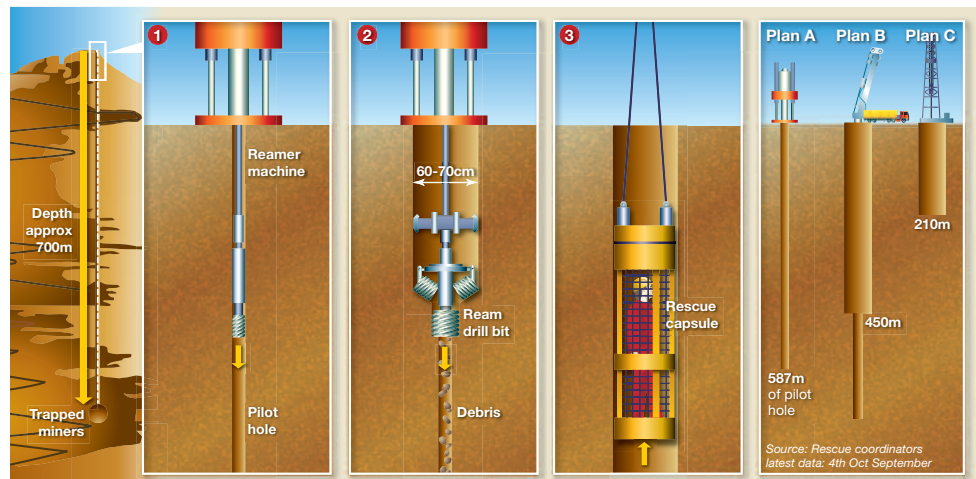
Two back-up plans are also drilling down to the miners, one using a deep exploration well driller fitted with a Down the Hole (DTH) hammer and the other using an oil probe.

The 5 August collapse of the copper mine's main access shaft happened about 400m below the surface, well above where the miners were working. A second collapse in the ventilation shaft thwarted escape efforts.

Chilean minister of mines, Laurence Golborne, ruled out a rescue through the mine's interior because of blocked ore chimneys and the high risk to rescuers. He also ruled out construction of a new tunnel because of the long delivery time. The chosen option was to drill directly to the miners. But the large depths, hard ground and need to accurately locate the miners meant Golborne opted for three simultaneous attempts, each using different technologies and locations.

The geology at the San Jose mine is mostly diorite, an igneous rock formed from cooled magma, considered to be medium-hard.

The first bore to start was the Strata 950 raise borer from South African firm Murray & Roberts Cementation. It is used to develop shafts or raises that can reach up to 8m in diameter. The operation involves drilling a pilot shaft downwards with a boring bit of about 300mm to 400mm in diameter, with a drilling speed ranging from 15m to 25m per day, depending on the rock type.



Subsequently, the shaft is slashed with a reamer. Its penetration speed will depend both on the type of rock and the final diameter of raiseboring, and normally an average of 10m to 15m of upward progress is obtained per day.

Traditional raises of upward progress have achieved over 800m in length. But it is more likely that a top-down approach will be taken and these have not been done beyond 400m, says Golborne.

Upreaming is quicker than downreaming because the reaction forces are more favourable for the borer. However, downreaming is often more manageable and is not subject to the risks that upreaming with a hybrid reamer will involve.

Murray & Roberts managing director, Henry Laas said, "rescuing the miners will be a challenging process. The mine is old and there is concern of further collapses. The rescue methodology therefore has to be carefully designed and implemented."

Rotary Vertical Drilling System (RVDS) technology, co-developed by Murray & Roberts, was applied to accurately drill a pilot hole to reach the trapped miners. After

which, the hole will be opened up to 660mm or 700mm to rescue the miners. The pilot hole was due to breakthrough as T&TI went to press.

Murray & Roberts spokesman Ed Jardim told T&TI there were no foreseen problems in reaching the miners, but there are chances of delays: "Changing of the drill bits takes time, especially if more changes in bits are required than planned as a result of the hard rock. So, possible time delays."

The raise borer is expected to have the shaft ready by the end of October.

The two back up plans are making good progress. Plan B, the truck mounted deep well borer, had managed 450m of completed shaft as T&TI went to press. The Schramm T130 uses reverse or conventional circulation of air and it can reach 1,000m in depth.

From time to time, it's used over an existing hole, which is used as a guide, to successively enlarge the diameter of the drilling. At the San Jose mine, this will be achieved using a DTH hammer, which has five hammers in one. It has never been used in Chile before.

In the first stage, the hammer widened the diameter to 300mm and in the second round a second

hammer is widening this to 700mm diameter. The average drilling speed ranges from 1m to 3m per effective hour of drilling, depending on the type of rock. So far the most bored in a day is 50m. Golborne raised initial concerns about this option as the equipment is unproven in Chile.

Plan C, the oil probe, has completed 210m of shaft. The RIG 422 is mounted on large scale crawler treads. Its tower is 45m high and it is mainly used in oil drilling. It requires a large area for its installation, some 80m by 100m.

Depth is not a concern as this rig has been used to drill more the 2,000m deep. It uses drill bits that drill into the soil in decreasing diameters; in this case it will start at 900mm and reduce to 700mm.

The drilling speed depends on the type of rock, and in the first 1,000m it can vary between 20 and 40m per day.

In early October, rescue workers reported a deviation in the drill alignment and used a back-up plan to bring the it back on course. The hole diameter was reduced to 445mm to redirect the bore.

There are hopes that either plan B or plan C will reach the rescuers before the end of October.

Jon Young

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Transportation salvation

The tunnelling industry in Southern Europe has taken in a hit during the financial crisis of the past few years. Though business is slower, there are transport projects picking up momentum in the Alps and metro work is carrying on in the east, Nicole Robinson finds

With the complicated geology alone in Southern Europe, there are plenty of challenges for the region's tunnelling

projects to overcome. Unfortunately, government cost-cutting measures are being added to that list, causing delays or stopping projects in places such as Spain, Portugal and Greece. But it's not all bad news, as major transportation projects, particularly in Italy and the Alps push forward.

Spain had transport on the brain with an ambitious high-speed rail agenda and metro projects happening among the nation's larger cities. The Ministry of Public Works wanted 7,000km of high-speed rail operational by the end of this year. A second phase with a 2020 deadline would bring the 300km/h network's total up to 10,000km making it the most extensive in Europe, with links to Portugal and France. Much of the work is now completed or on its way to completion and there is very little infrastructure work left to do in Spain, says Remo Grandori, president of Seli.

In Spain, he explains, the infrastructure boom was financed by the European

Union Community. "It was foreseen that this money would have a limit—when the infrastructure reaches the European standard," he says. "Now this moment has come and unfortunately it was at the same time as the financial crisis happened and the combination of the two has made for a disaster. But it was foreseen. That's why Spanish companies already started two, three years ago to look at the foreign market."

For example, the 6km long La Cabrera railway tunnel in Valencia is set to open before the end of the year. Work is underway constructing the first phase of Bilbao's new metro Line 3. At the moment, Bilbao's Metro network consists of Lines 1 and 2, and two more are being studied, Lines 4 and 5, which could extend public transport to the eastern side of the city. This expansion is part of citywide recovery effort having lost much of its industrial business.

Tunnelling on Line 3 is using roadheaders as the main means of excavation in a sequential excavation process (see page 25). Two contractor joint ventures won contracts for phase one tunnelling, which

runs from Casco Viejo to the surface at Etxebarri/San Antonio and is currently being undertaken.

Times aren't as tough in Italy compared to Spain because it wasn't as dramatically affected by the financial crisis, says Grandori. "There are jobs, but it's not a brilliant period." Metro projects in Milan and Rome are offering work. There are high-speed rail opportunities in Florence, and the 16m diameter underground highway being excavated by TBM between Bologna and Florence is quite notable for the region.

Busy in the Alps

This month will see the first final breakthrough between Sedrun and Faido at the Gotthard Base Tunnel, on 15th October. At the Sedrun segment, additional exploration of the rock under the breakthrough area took place this summer as a core bore with a length of more than 220m was driven west from a niche in the south drive. Except for relatively short lengths, constructor AlpTransit Gotthard found that the bore indicated generally good geological conditions.

Four Herrenknecht gripper TBMs have been used to bore the 57km rail tunnel through the Swiss Alps. As of 1 September, 97.5 percent of the total 153.5km of tunnels, shafts and passages have been excavated. Roughly 38km on both the west and east tubes have completed linings and are ready for railway technology to be installed. Completion of the USD 9bn project is expected for 2017, and it will be the longest road or railway tunnel in the world.

To the east, the Alps will also see tunnelling for the Brenner Base Tunnel between Innsbruck, Austria, and Fortezza, Italy, in as early as two years. The 55km rail tunnel will consist of two tubes, each with a single track, interconnected every 333 meters. The tunnel will connect with the existing underground Innsbruck bypass, for a total railway distance of 62.7km. Another



Left: The Alps are seeing several projects, like the Brenner Base Tunnel



Above: Excavation of an exploratory tunnel prior to the main Brenner Base tunnels

tunnel in between and 10m-12m below the two main tubes, is first being excavated for geological and hydrogeological exploration. This must be completed before the main tubes can start construction.

The first lot, from the Italian side, has seen 10km excavated, and a breakthrough at 10.5km—where a 1.8km lateral access has been constructed—is expected in November. For the 5.6km Austrian lot, conventional driving started in December 2009 and 1.4km has been excavated. Work on a 2.4km long lateral access is at the 300m point. Three more lateral access points in Austria must be completed before the main tunnels can go ahead, says Simon Lochmann, head of communication for the Galleria di Base del Brennero/Brenner Basistunnel (BBT), which is overseeing the project.

If all goes well, the BBT hopes to start tendering contracts for the main tunnels at the end of November. It is waiting for the final green light from Austria's Ministry of Transport, which is reviewing all large infrastructure projects and will finish its evaluation in mid-October.

Lochmann says there is nothing to worry about in this evaluation. "We are quite confident that this has absolutely no impact on our project because we have submitted a new prospectus for the first two years, not to do as much work as was expected." Work originally planned for 2011 and 2012 will start off slower or later on but should

make absolutely no change to the project, he explains. EUR 800M (USD 1.14bn) of the funding will come from the European Union until 2013, which should cover about 27 percent of costs. Remaining funds are being covered 50/50 by Italy and Austria.

There is also the nearly 52km long base tunnel that will connect Italy with France through the Alps on the Lyon-Turin railway. Once the project is completed, travelling between the two cities by train in either direction will be a journey of less than two hours, compared to the current four hours. Plans call for a bored tunnel at an altitude between 570m and 750m above sea-level, with a maximum slope of 12 per cent.

So far three access tunnels in France have completed as of June this summer. Around the same time, a new preliminary design had been presented to Italy. Following an inquiry and approval by Italian public authorities, is scheduled for late 2010, according to the company in charge of the project, Lyon Turin Ferroviare (LTF). In a report for September 2010, LTF says excavation for the main tunnels can be expected in 2013 for operation in 2023.

Commuting in the east

Following Greece's financial turmoil this summer, new projects have been delayed and existing projects are struggling, due to the lack of finance, says Grandori. Only major projects, like metro work in Athens and Thessaloniki - which combined carry a EUR 2bn (USD 2.8bn) plus price tag - seem to be on track to go forward. In Athens, building a new metro network for the city has been an undertaking for nearly 20 years, since the Athens Metro Base Project started in 1992. At the moment, Athens Metro network is focused on the EUR 515M (USD 710M) extension towards

western suburbs, terminating in Piraeus. The project includes 7.6km of underground line to be completed by TBM and six new stations. Six joint ventures have expressed interest in constructing the project, which is expected to start in 2011.

In Thessaloniki, construction started in June 2006 on the 9.6km long metro line plus 13 stations. TBMs have bored more than 5,000m as of August. Already, two extensions on the Thessaloniki Metro are being weighed up. A 4.8km underground line towards Kalamaria with five stations was put to tender in May 2009, with the goal of awarding the contract in 2011.

Meanwhile in Istanbul, crowded and limited transportation leads the way for the Marmaray Project, a commuter rail line that will carry 75,000 passengers per hour in each direction via an immersed tube under the Bosphorus Strait. With two road bridges, it's the third crossing to connect both sides of the city.

Work has been delayed by extensive archaeological investigations as one of the four new stations is to be located in the heart of the city's historic district and another has been discovered to be a former Byzantine Port (see page 16). Though 2010 will mark a number of milestones for the project, including the possible opening of one track of the 1,387m immersed tube tunnel section (see page 20).

The entire commuter rail upgrade has a USD 3bn price tag, with one of three contracts, for the construction of tunnels and stations, awarded to Taisei in 2004. The other two contracts concern commuter rail and rolling stock production. Taisei says, with the ongoing investigations, it's uncertain whether the line will be operational by 2014 as is currently planned. ■

Gotthard Special

Next month T&TI will publish a special supplement on the Gotthard Base Tunnel project, offering a thorough investigation into the project from start to the upcoming breakthrough. Regular subscribers can expect to receive the supplement with the November issue of T&TI.



A city steeped in history breaks new ground

Constructing an underground rail connection for the European and Asian sides of Istanbul will improve traffic and environmental conditions in the city, once completed. Along the way, contractor Taisei and joint venture partners are employing NATM, TBM, immersed tube and cut and cover excavation methods to build the Bosphorus Crossing, Nicole Robinson reports

Future underground Sirkeci Station is located in the heart of Istanbul's historical district, teeming with tourists, palaces and mosques.

Work on the Marmaray Project to build a tunnel connecting the European and Asian sides of Istanbul is the first time this area

has seen excavation, requiring special permission and offering up an underground treasure trove of ancient structures for archeologists.

For contractor Taisei and its joint venture partners Gama and Nurol, it may be harder to muster the same enthusiasm.

Understandably so—the contract originally called for 30 days of archeological investigations at the site of one of the access shafts, for example. Six years later, this particular shaft is still being surveyed and it's unknown when a full excavation can be completed. Masahiro Iwano, project manager for Taisei points out, beneath that there may be Roman ruins.

Excavations at the future site of Yenikapi Station, once a Byzantine-era port, have revealed almost 30 ships and many have been moved to one of the city's museums. One of these vessels is still sitting partially excavated in the middle of the worksite, as archeologists weigh their options for removal. Yenikapi is the biggest station of the project.

When Taisei started working in August 2004, its contract for engineering, procurement and construction for 13km of track works and associated structures and stations was worth USD 1,218M (assuming the current exchange rate) and would last for 56 months. This contract is part of a larger USD 3bn project totaling 73.6km of track, mostly above ground.

The client, Turkey's Ministry of Transportation, the General Directorate of Railways, Harbors and Airports Construction (DLH), granted the Taisei joint venture an Extension of Time, extending it to 110 months and increasing the contract to USD 1,800M. The reason for this was mainly due to the extensive archeological investigations, says Masahiko Tsuchiya, design manager on the Marmaray Project for Taisei. The completion date then moved from 2013 to 2014 at the earliest.

Both Yenikapi and Sirkeci Stations are located on the western, European side of the Bosphorus Strait, which connects the



Left, top: Steel sleeves for elements E1 and E11 **Left, bottom:** The route for the immersed tube and underground rail line



Black Sea in the north with the Marmara Sea in the south, dividing Istanbul (Figure 1). Two other stations, Uskudar on the eastern side and Kazlıcesme Station to the west are included in the contract, as well as electrical and mechanical work, diverting the existing railway and the time-absorbing archeological investigation.

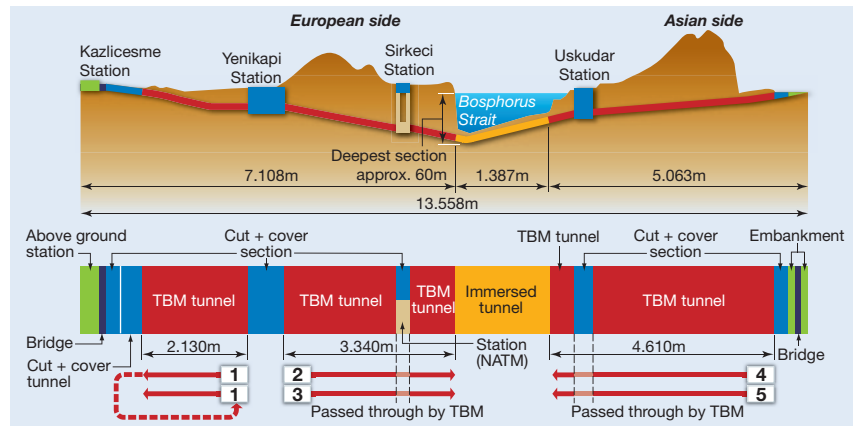
Still, the Marmaray Project continues moving ahead. All 11 of the tube elements for the 1,387m immersed tunnel connecting the western and eastern underground rail lines are installed (see page 20). One of the project's five TBMs is starting the final leg of its excavation on 20 September. This TBM will dock with the most western immersed tube element and Ivano expects from early next year it will be possible to walk from one end to the other on the immersed tube's southern track.

Making the connections

Four Hitachi Zosen slurry TBMs of 7.8m diameter fitted with roller cutters have been chosen to mine tunnels on either side of the immersed tube where the ground consists of mainly hard rock. An EPB from Lovat has been chosen to mine both of the 2,130m tubes between Yenikapi and Kazlıcesme Stations where the ground has a stiff clay consistency.

Two of the immersed tube elements (E1 and E11, one at each end) are equipped with a specially-designed steel sleeve into which the four slurry TBMs drive and connect. Within each sleeve is a ring of rubber packing that inflates with hydraulic pressure to grasp the TBM and make a watertight seal. The steel sleeves on E1 and E11 also have an additional, temporary bulkhead on the end. Just before backfilling the area around the placed element with premixed soil, the temporary bulkhead is removed and jelly-like LW material is injected and frozen. Tsuchiya describes it as a kind of water and glass, developed by Taisei's Research and Develop Center specifically for the Bosphorus Project. "It has a very interesting characteristic," he says. "It becomes solid after casting, similar to concrete. Once it experiences the freeze/thaw cycle, it becomes liquid. This characteristic is very much suitable for docking of TBM into immersed tunnel."

The man-made pre-mixed soil helps prevent liquefaction when the TBMs drive into each connection. Freeze rings around the steel sleeve froze the LW material as the TBM passed through, which removed most of it, requiring only a small amount around the TBM shell to actually be frozen. When it thaws, the material becomes liquid and runs away, and is replaced with a sealing



Above: The alignment and TBM routes for the Marmaray Project in Istanbul

grout. The TBM can be dismantled and a permanent in-situ lining is installed in the connection. Because there are no access shafts, all four TBM shells will stay behind. So far, only TBM 4, mining track 1, has been dismantled and removed.

Built into the steel sleeves is a seismic joint for each end of the immersed tunnel. The alignment is roughly 16km away from the North Anatolian Fault line and the employer, DLH, expects with a 65 per cent probability that there will be an earthquake in the region, registering 7.5 on the Richter Scale. Taisei had included its decision to use the joint when bidding for the project. The flexible joint consists of two omega-shaped rubber gasket rings sandwiched between steel segmental linings, measuring 30cm thick and 100cm long to the longitudinal direction of the tunnel. The joint has been designed to accommodate seismic motion up to a 7.5 on the Richter

Scale, handling plus or minus 10cm in longitudinal direction, and plus or minus 5cm in other directions.

The in-situ lining will only be used in the four connections. The rest of the tunnels are being lined with pre-cast reinforced concrete segments, manufactured by Taisei, which estimates approximately 13,000 segmented rings will be used in total. Each ring has a configuration of six segments and one keystone and a 7,040mm internal diameter. The segments are 1,500mm wide and either 300mm to 320mm thick.

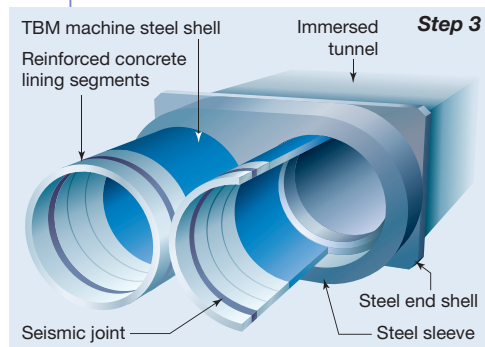
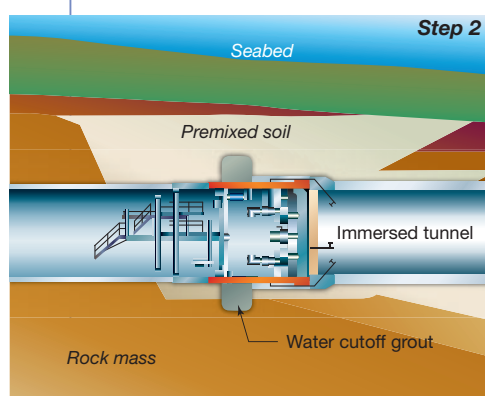
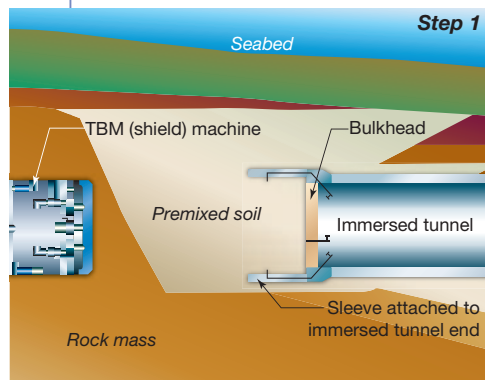
Station location

On the eastern side, Taisei is building Uskudar Station by cut and cover, and on the western side, Kazlıcesme is being built above ground, and Yenikapi by cut and cover.

At Sirkeci Station the platforms, access passages shafts, main passage and ventilation shaft are being built using NATM,

Below: TBM 4 breaks through at immersed tube element E11





excavating vertical and horizontal tunnels ranging in width from 6m to 10m. This had been chosen because space on the surface is restricted by the station's location in the city centre—though the station's entrance will be built by cut and cover. Emergency passages between the TBM tunnels will be excavated roughly every 200m by NATM.

Muck removal is restricted to four hours from 20:00 to 0:00 for the NATM at Sirkeci. With its prime location in the historic district, it's against the law for removal to happen during the day, explains Iwano. The muck is stored in a temporary stock area and one or two days a month it is

Left, from top to bottom: The TBM joins with the immersed tube after mining through backfilled premixed soil and entering the steel sleeve. The steel shell of the TBM will be left in place;
Below: The flexible seismic joint on the steel sleeves attached to element E11; there is one for E1 as well

Scope of work

Immersed Tunnel: 1,387m

Shield Tunnel: 9,360m

NATM: Sirkeci Station, 250m platforms, crossover tunnels, cross passages

Cut and cover stations: Sirkeci Station entrance, 760m at Yenikapi Station, 310m at Uskudar Station

At-grade Station: 225m at Kazlıcesme Station

Other structures: Cut and cover tunnels, bridges, ventilation buildings, etc.

transported away from site. The historic nature of the neighbourhood also meant 104 buildings needed to be checked for whether or not they needed reinforcement before the construction started, near Sirkeci alone. Across the project, in total, some 170 buildings have been checked.

Sirkeci is also the only station of the four that will have two side platforms rather than one central platform. Originally its excavation had been planned using two access shafts, but with an embargo on any further work at the east shaft, the excavation has been changed.

At the time of T&T's site visit TBM 3 had finished its run from Yenikapi to Sirkeci Station and was having cutter heads replaced and other maintenance before it passes through Sirkeci Station's southern portion, which has had its concrete in-situ lining completed. TBM 3 should begin tunnelling through to its connection with immersed tube element E1 by the start of October. Taisei is working 24-hours-a day and the TBMs are stopping on average for scheduled maintenance every 200m to 300m, which usually works out to be once a month. TBMs 2 and 3 both have 57 disc cutters on the face. On the centre there are 17 pieces of 17in (43.18cm) and on the gauge cutter there are 7 pieces of 19in.

In the Sirkeci's northern side, the cutting faces are working on excavations on both ends and it should be another three to four months until the concrete lining will be put in place before TBM 2 can pass through.

Consulting with archeologists from U.S. and UNESCO, among others, Taisei has spent at least six months discussing various options for deconstructing and moving the various artifacts discovered at the eastern access shaft site. For now they are wrapped in cloth or Styrofoam, with the expectation that it will take several months to remove them, and then shaft excavation can start again.

The delay affects not only the construction schedule for Sirkeci Station, but also the tunnelling schedule because the east shaft was to provide access to bring in equipment like cabling and pipes for areas around the tunnels like walkways. Tsuchiya says client DLH assumed at the beginning of 2010 all archeological excavations would be completed by April, which they are not, entitling Taisei to yet another EOT.

Only time will tell if 2014 marks the year Istanbul's commuters first board trains running under the Bosphorus—not to mention how much additional display space will be needed in the city's museums. ■





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A sinking success in Istanbul

Conceptual design drawings, dating back to Turkey's Ottoman Period, show ambitious plans for a tunnel immersed under the Bosphorus Strait in Istanbul. It may have been a pipe dream back then, but that is no longer the case. Nicole Robinson visits the immersed tunnel of the Marmaray Project

Technological advancements in tunnelling and construction would certainly perplex artists who created sketches for a potential tunnel through the Bosphorus, roughly 150 years ago. Travelling between the two sides of Istanbul had been limited to boats until the 20th century when two different bridges were eventually built to take cars across the strait. Even now, ferries taking commuters from the more residential Asian side to the commercial and touristic European side and back, are packed in the mornings and evenings.

Turkey's Ministry of Transportation, the General Directorate of Railways, Harbours and Airports Construction (DLH), wanted a solution that would reduce traffic congestion and target its side effects, in particular the pollution that accompanies

road traffic. Updating the city's mass transit system became a necessity and the DLH narrowed its sight on a rail tunnel, finally fulfilling the Turkish dream of tunnelling under the Bosphorus, says Masahiko Tsuchiya, design manager on the Marmaray Project for Taisei, which won the now USD 1,800M contract with a joint venture partners Gama and Nuroi in 2004 (see page 16).

The immersed portion of the tunnel measures 1,387m and will eventually be met on the European side with tunnel bores made by two Hitachi Zosen slurry TBMs of 7.8m diameter. On the Asian side the immersed tunnel has already connected

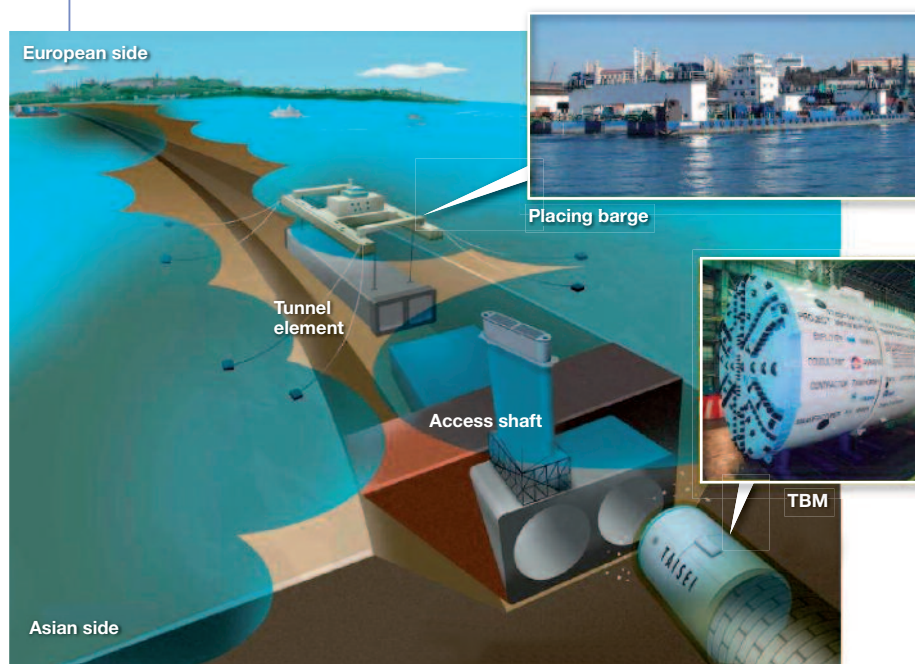
with bores made by two more Hitachi Zosen slurry TBMs (Figure 1).

Due to seismic activity in the region, the tube had to be designed to handle an earthquake of up to 7.5 on the Richter Scale. This was achieved by fitting flexible joints made up of two omega-shaped rubber gasket rings sandwiched between steel segmental linings at each connection point. Other considerations for the construction included immense water pressure at the alignment's deepest point, 60m below water, and the strait's rapid, dual-layer current. The top layer of the current travels north to south at 5 knots maximum (2.5m/second), but the bottom layer of the current travels south to north at 2 knots maximum (1m/second).

In August 2005 Taisei started to prepare the seabed trench that would create a stable place for the tube elements to be installed. A dredging machine from Japan was used to evacuate the trench, working at a rate of about 30 cubic metres per bucket. Approximately 1M cubic metres of undersea deposits were dredged, says Tsuchiya. Any contaminated material excavated was taken to a confined disposal facility and clean material was disposed of into the Cinarcik ditch in the Marmara Sea, with the approval of Turkey's Ministry of Environment and Forests. After completing the dredging in July 2007, a subsea grader was used to create a foundation layer, which was necessary before tube elements could be installed.

Most of the ground below the Bosphorus Strait consists of marine deposits with a small area of Belgrad formation. Two areas within the immersed tunnel alignment required ground improvement. One area, where the risk of liquefaction existed deeper than 4m from the tunnel's base elevation, Taisei used compaction grouting. A mixture of water, cement, sand and

Below: Figure 1 – A placing barge lowered elements into a pre-excavated trench. TBMs join the immersed tube at E11





additives, for durability and cohesion of the grout material, was injected through steel pipes dug by four boring machines. A total of 3,300 piles were made, down to 8m at the greatest depth. The other area within the immersed portion of the alignment that posed a risk was less than 4m deep from the base and only required dredging and replacement material.

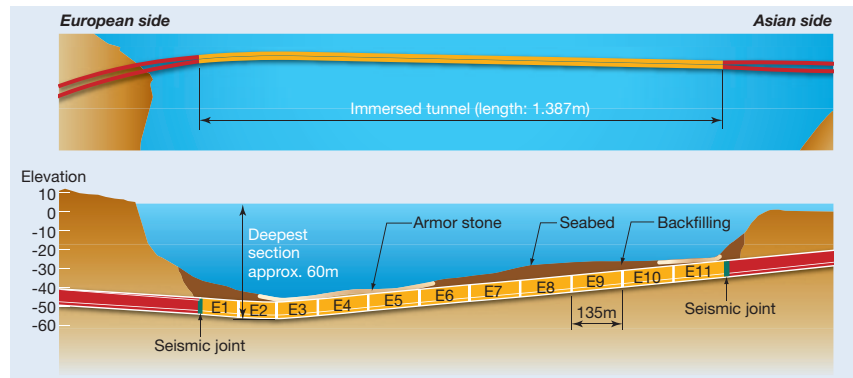
Floating the elements

The 11 immersed tunnel elements each measure 15.3m wide and 8.6m tall with two compartments for the rail lines. Each compartment has a 1.4m escape way and a squeeze way for maintenance. The length of the elements varies, with eight measuring 135m, two at 98.5m and one measuring 110m. Their weight ranged from 18,000t to 14,000t for the smallest. To withstand the high water pressure of the Bosphorus, waterproof steel plates 7mm thick are used on the bottom and both sides of the element, with corrosion protection. Because a steel membrane couldn't be used on top of the tube, it is connected to a waterproof sheet, which is then covered in a layer of protective concrete. The water can't damage the tube, and neither could a sinking ship, explains Tsuchiya.

Tube elements were prepared in two phases: manufactured at Tuzla Port, in southeast Istanbul, towed 10.8km and tested at nearby Buyukada Island. Two facilities were used at Tuzla, owned by DLH, to speed up the fabrication process, explains Tsuchiya. First the steel structure of the base part was built in dry docks and then floated to a pier for construction of the upper part, allowing the next element to start. After testing and final preparations for the immersion at Buyukada, one by one, elements were towed another 28km to their installation site.

The Marmara Sea is too shallow to use a route along the shore between Tuzla and the tunnel. Instead, elements were towed around Buyukada and other nearby islands for a total of approximately 40km. It took roughly one night to tow each element and about one day to then immerse it, Tsuchiya says. The first element, numbered E11, was immersed on 23 March, 2007. This piece would later host the connection with the TBM mining from Uskudar Station, saving the deepest point of work (between elements E2 and E3) for last. The final element, E1, which will connect with TBMs

Above, right: A temporary steel shaft is connected to element E11 **Right:** The placing barge and E11 before immersion



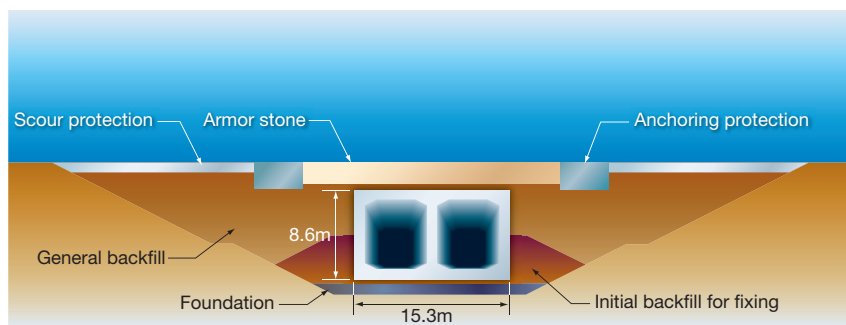
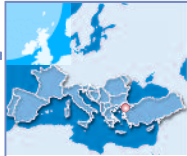
Above: Figure 3 – Immersed tunnel elements beneath the Bosphorus Strait

from Sirkeci Station, was immersed on 23 September, 2008.

The immersion

Much of the immersion work on the Marmaray Project depended on the weather and sea current conditions. The employer's requirements said the immersions could only be carried out when the strait's current was less than 3 knots (1.5m/second), leaving the contractor to find small windows of time to safely float and immerse each element. Monitoring systems like GPS and ultrasonic waves were used to identify the element's location and place them in the trench. The more traditional method of using divers to guide the immersion was ruled out because of the tunnel's depth. Diving would be inefficient as it could take nearly an hour to swim down or back up. In particular, it was just too much of a risk to have humans diving





Above: Element E11 is immersed by ballasting 3 per cent of the tube's weight
Left: Backfill is added for protection and to return the seabed to its original profile

with the water's intense pressure, says Tsuchiya.

The Bosphorus is a busy marine crossing with ferries and other local and international traffic during the day. A temporary steel tower, weighing about 200t, 3m wide, 8m long and 35m tall, was installed in the Bosphorus as the only access shaft to the tunnel before the TBMs arrived. A portion of the shaft had been attached to element E11 before it was immersed in March 2007 and the rest of the shaft was lowered down later that spring. Once attached to E11 the contractors were able to gain access to each immersed elements via the shaft. A temporary jetty and bridge connected the top of the access shaft tower to the mainland. With the strait's strong current and traffic, a barrier had been set up to prevent ships from hitting the tower, in the event one loses control.

The immersion barge, which needed to stand in the Bosphorus holding elements weighing up to 18,000t, had hulls 90m long and 8m wide, with four lifting lugs each with a 250t lifting capacity. The barge lowered an element with the lifting hooks attached to the lifting lugs.

The elements were buoyant before the water ballast was poured into them. "The

placing barge was clinging to the tube, which was buoyant itself during towing of the tube," says Tsuchiya. "Just before starting immersion of the tube, we ballasted to 3 per cent of the tube weight by pouring sea water into ballast tanks installed in the tube via plumbing pipes and valves which could be controlled remotely in a commander's room of the placing barge."

Three per cent of the tube weight is approximately 540t, which could safely be lifted by the barge and its four lifting lugs.

Once it touched down, the ballast tanks were increased to 5 per cent. Tsuchiya explains the heavier ballast was preferred to minimise lateral shift of the elements from the rapid flow of the Bosphorus.

The elements were fitted with jacks to provide horizontal and vertical movement—on both ends of E11 to adjust its orientation and on only one end of subsequent elements to line up—and were lowered within about a metre's distance to the previously immersed element. After verifying its location, it was brought horizontally using guides to meet with the previous element. The Gina gaskets on the elements have a soft rubber nose that made contact with the previously installed element, and a pulling

jack on the existing element was extended to draw in the new element.

As the bulkheads at each element are slightly recessed, when two elements were pulled together a chamber of water was created between them approximately 2m wide. A tap in the bulkhead of the previously immersed element was opened. About a cup of water came out and the elements were drawn close together by the unbalanced hydrostatic pressure. The remaining water needed to be pumped out.

Once an element is connected to the previous one and the connection was sealed off from the water, the foundation concrete was completed. Lock filling was applied to avoid any horizontal movement to either side, and only after the backfill for each element was finished, another one could be immersed (Figure 3). Ballast tanks were emptied after installation. Each element required about a month of work, says Tsuchiya. When the final element (E1) had been locked in place, the tunnel was covered in backfill and a protective armor was applied to avoid damage from anchors or sinking ships.

All of the elements are completely embedded so the seabed's profile is the same as it was before the construction started. In areas where the backfilling is less than 4m, armor stone has been placed for additional protection. Maintaining the same seabed profile was required for environmental purposes, including fish migration. ■



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Heading for Basque airport

Construction has commenced on Bilbao's new metro Line 3, which will eventually provide a valuable link to the city's airport. The project is not only part of a major expansion of the public transport system, but also of the city's overall facelift and reorientation to recover from a largely disappeared industrial past. Current tunnelling features roadheaders as the main means of excavation in a sequential excavation process. Maurice Jones reports

Two contractor joint ventures won contracts for the tunnelling on phase one of Line 3 of the metro that will run from Casco Viejo to the surface at Etxebarri/San Antonio. Later, the line will be extended to the airport (Aireportua Station) from Casco Viejo in another contract. Currently a joint venture of Altuna y Uribe, Sacyr and Cava called UTE Metro Txurdinaga, is driving the running tunnels and associated ventilation and escape tunnels with two Sandvik

MT720 roadheaders equipped with Sandvik's ICUTROC cutting technology, while a second joint venture (UTE Linea 3) of Comasa, Cycasa and Nortunnel, is employing the new Sandvik MT520 100t-class roadheader to meet the more flexible needs of ancillary excavations and multiple drives in station caverns etc., as well as an MT720 for running tunnels.

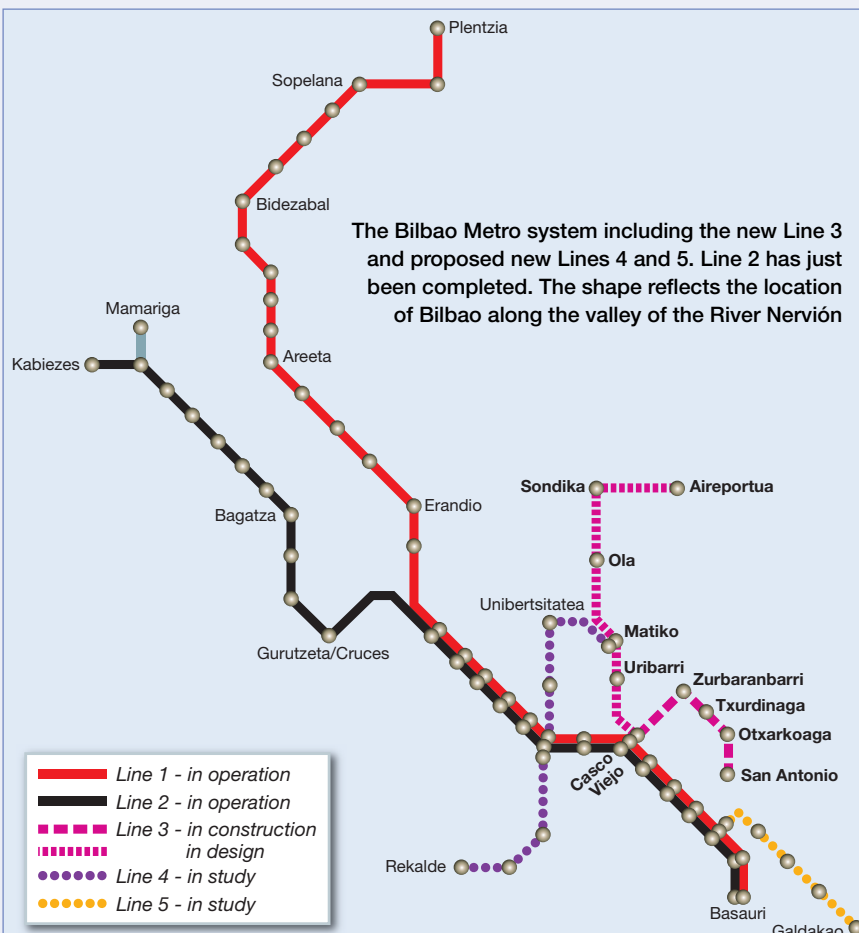
Two more MT520s are currently being used for infrastructure preparation in Sochi, Russia for the 2014 Winter Olympics

Previous roadheaders

Experience with various models of roadheader and other excavation methods has provided input for the design of the MT520 and the modern Sandvik roadheaders, as well as conditioning the opinions of the client engineers on what form of tunnel excavation will work.

At an assembly of Sandvik customers, project participants and media in Bilbao, director of construction for the developer/client, RTS (Red Ferroviaria

The Bilbao Metro



Lines 1 and 2 form the current Bilbao Metro network, but these are only part of a quite complex public transport system of different modes of rail and bus transport covering the city and Greater Bilbao. This includes neighbouring towns such as Portugalete, Sestao, Lagota and Barakaldo. However, there are still gaps in the service network, most of which are now being addressed as part of the city and region's redevelopment.

Line 3, now under construction, is expected to carry 71,000 riders in its first phase, according to Bilbao council forecast. Unlike the first two lines operated it will be operated by ETS (Euskotren), an organisation that already runs trams and local surface railways. Euskotram manages the city's tramway system while Cercanías RENFE and FEVE manage to other sections of the rail network.

Proposed Lines 4 and 5 expand public transport in the eastern end of the city are under study. The University of the Basque Country at Leioa has requested Line 6 to be constructed between Leioa and Getxo with the airport in Asua Valley.

Currently the Bilbao Metro, which has been operating since 1995, has 40.6km of rail tracks with 38 stations, 22 of which are underground and 16 on the surface. Lines 1 and 2 form a Y-shape along the valley of the River Nervión. This has necessitated several crossings under the river. However, the Line 3 construction is all on the northeast side of the river.

Metro annual ridership is expected to reach 100M passengers, once the network is completed, from a city population of a million.



Above: Josef Pilcher, Sandvik product line manager for roadheaders

Left: Sandvik MT520 at the face with transverse cutterhead

Vasca), José Francisco Borde, explained the activities of RTS and aspects of tunnelling on Lines 1 and 2 of the metro. Most of the strata in and around Bilbao are limestone of various degrees of hardness (up to 120MPa UCS) and folding. Early attempts at using drill-and-blast tunnelling caused problems with residents due to vibration, noise and the relatively shallow (sometimes as little as 3m cover) work in places, and so now there is a ban on its use. Borde explained, however, that earlier roadheader excavation had experienced mixed levels of success, sometimes due to the machine speeds and cutting capabilities not being up to good progress in the harder limestone.

This experience, in particular the importance of cutting speeds matched to the type of rock being excavated, was taken into consideration in the design of recent Sandvik roadheaders including the new MT520. Another option of using TBMs

was rejected during planning in the 1990s due to the difficulty of amortising the investment costs then.

New design

The new prototype MT520 model of roadheader being used on Bilbao Metro Linea 3 is a 100t class (weight 115-120t depending on cutterhead) that fills a perceived gap in the range between lightweight units mainly for soft rock and heavy-duty machines such as the two Sandvik MT720s also being used on Line 3. It combines flexibility with capacity, being designed for tunnels of length 500-2,500m and single-position operation for sections of 40-90sqm. However, the unit's flexibility of manoeuvring and quick service connections allows it to cover larger sections from multiple lines of attack with ease.

Sumping from the working position can be achieved either by forward crawler track movements or 1.2m of telescopic action

within the cutter boom. Cutting speed is up to 2.9m/s from a 315-kW motor. The unit carries a total of 537kW power for all functions.

In addition to excavation, a number of optional modules will allow the MT520 to accommodate support functions such as arch lifting, rockbolt installation and concrete spraying.

The current roadheader design philosophy, as explained by Sandvik product line manager Josef Pilcher and senior roadheader engineer Manfred Meier, is to form the whole unit out of assembly groups, or modules, in order to meet customer exact requirements at a reasonable cost, rather than to compete on cost primarily by producing standard models that may not meet exact operational requirements. Thus the new MT520 is broken down into the undercarriage, loading device, cutting unit, rear stabiliser, working platform, driver cabin and double-chain discharge transfer and discharge conveyor, plus a range of options as listed in the separate box.

One option is an 8m cutting height rather than the standard 7.1m. This is achieved by large spacer units below the boom support and the cab (thus preserving face visibility).

Another option is the possibility to exchange between in-line (longitudinal) and transverse cutterheads. In-line cutterheads tend to be the best for accurate profiling, but transverse cutters are better for hard ground and loading since the cutting action assists in loading the apron and its twin rotary loaders (spinners) and double-chain conveyor. Changing the cutter and its gearbox takes a maximum of one shift, but both can employ the full cutter drive motor power of 315kW.

Overall the main foci in developing the MT520 were productivity and safety. The cabin is equipped with air conditioning and

Below, left: Operating the MT520 from a spacious cab;

Below, right: Rear view of the MT520 showing truck-loading conveyor





ergonomic controls and is mounted on efficient shock absorbers. The overall design is stabilised to minimise vibrations, both for operator comfort and accuracy in laser-based directional and profile control. Standard dust control is low-pressure water sprays around the cutterhead, together with an integrated dust extraction systems lining to dust scrubber back down the tunnel. One option is for high-pressure water sprays, also for pick cooling, using an on-board pump.

Although the maximum rock strength for which the Sandvik MT520 is designed is 100 MPa (Uniaxial Compressive Strength – UCS), it is expected that it will be called upon to tackle up to 120MPa in places on Line 3. At 100MPa it has been decided that Sandvik's innovative ICUTROC hard-rock cutting system is not necessary, although the MT720 units used for the running tunnels are so equipped.

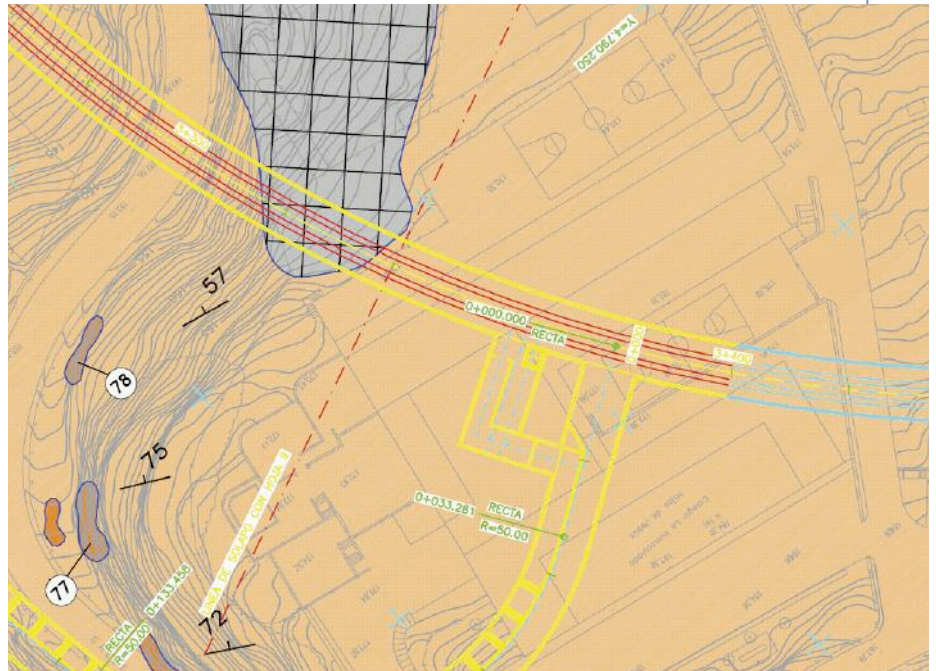
Finally, the option of a laser-based guidance and profiling system has been developed by Geodata, and is used on the MT520 at Bilbao. The system provides automatic profile control and guidance so that site engineers can program the required tunnel profile into the machine's control system. The operator display includes the planned profile, excavation and position of the cutterhead and provides a graphic warning when the cutterhead is approaching the planned profile limits. Automatic operation provides great accuracy to minimise overbreak, thus reducing support concrete lining costs.

Construction

In the first phase of Line 3 construction there are seven stations, six of which are located in Bilbao district (Otxarkoaga, Txurdinaga, Zurbaranbarri, the interchange with the existing Casco Viejo station, Uribarri and Matiko), while the other, San Antonio surface level station, is located in Etxebarri district. The running tunnel is to accommodate double-tracks over a total length of 5,885m.

In addition to the running tunnels and main station excavations with normal passenger access ways, there are a number of ventilation and emergency passages to be excavated, some of substantial length. This is a consequence of the hilly topography of the area and the often high-density urban development, both of which have already placed great demands on the design of the route to achieve feasible grades and station locations.

The main tunnelling work has commenced from an access and emergency ramp at the approximate



Above: Plan of the main start point of Line 3 construction with both contractor jvs starting work here. The access ramp and tunnels are outlined in yellow and the planned rail track route in red. The excavations will form an emergency egress

Right: The Sandvik MT520 at the main construction portal. Note sprayed concrete and reinforcement in limestone

dividing line (distance mark 3+400km) between the two joint venture contracts between Txurdinaga Station and Zurbaranbarri Station. Here the MT520 was used to drive the access ramp, and is also being used to excavate service tunnels, cavern and part of the eastern running tunnel. The access ramp is in horseshoe profile, 7.2m high.

Following excavation of the ramp the MT720s were introduced mainly for driving the running tunnels. The contracted run for the UTE Metro Txurdinaga joint venture goes from mark 3+400 (kilometre) to Casco Viejo Station. Until mark KM4+350 the tunnel is a double-track design with a 58sqm section (for 1m gauge track) and running for 950m through Zurbaranbarri Station. The station itself will be accommodated in a cavern excavation of 190sqm section and stretching for 110m along the rail track route.

Beyond marker KM4+350, approaching Casco Viejo Station the tunnel will divide to form two single-track tunnels (North Branch and South Branch) leading to opposite ends of this station.

The ancillary excavations previously



mentioned for Zurbaranbarri include the following:

- Station access including two construction drives and a lift shaft;
- Emergency ventilation drifts (two at Zurbaranbarri and one at Casco Viejo), plus an air extraction well under Zurbaranbarri Station);
- A long combined emergency exit and ventilation passage from the tunnel split to surface at Etxebarria Park.

In the opposite direction the UTE Line 3 joint venture is driving the running tunnels through to surface before Etxebarri/San Antonio Station, to include Txurdinaga and Otxarkoaga Stations. This contract has a



Roadheaders from Austria



Rear of the MT520 at the portal showing counterbalance and truck loading conveyor

Austria has long been a centre of roadheading excellence, even though drill-and-blast tends to be preferred traditionally in the hard rock generally found in the nation. Sandvik production here is based on the old Voest-Alpine operation that Sandvik Mining & Construction purchased.

Sandvik engineers there have ambitions to extend the application sectors for roadheaders, both geographically and in types of tunnel, and part of this drive is to take over research and development on roadheader cutters, both transverse and longitudinal, from the main development centre of Sandviken since the main applications data is being accumulated in Austria. However, the cemented-carbide inserts for the picks will still be produced in Sweden.

Sandvik MT520 spec

Total weight:	110-115t
Cutterhead power:	315 kW
Max. cutting height:	7.1m (optional extension for 8.0m)
Max. cutting width:	10.3m (optional extension to 10.8m)
Options:	Increased cutting height module; inline cutterhead (transverse is standard), diesel drive for rapid transit, slewing belt conveyor for truck loading, water hose and cable reel, high-pressure ring spray systems at cutterhead, automatic fire suppression, laser-based control system for direction, profile control and operator visualisation.

length of 2,180m of main tunnel with cover varying from 5m to 118m. The two stations are 110m in length with cover of around 18m. Two access ramps are of the same section as the running tunnels with a grade of 15 per cent. In addition there are five exit ramps and 12 shafts of 3.60m diameter totalling 235m. The Phase 2 extension to the airport has a planned length of 1,875m.

According to the contractors, all excavation follows NATM with sequential excavation and a set of support design installed according to the condition of the rock discovered during excavation. The running tunnels are planned for two excavation

phases of a 6m-high top heading and then the roadheader withdrawn to excavate the small bench.

Initial/primary support consists of a layer of sprayed concrete applied by a Putzmeister-Sika PM500 robotic system. If necessary, the ground is reinforced with Swellex rockbolts and steel rib arches, according to the condition, before covering with more sprayed concrete.

Before installing permanent support, an impermeable membrane will be placed over the reinforced sprayed concrete for water control. The final design support lining is a 300mm ring of cast-in-place concrete formed over the membrane and final horseshoe-section tunnel will be approximately 6.63m high by 8.4m wide.

In Zurbaranbarri Station the large cavern of elliptical section, approximately 17.8m wide, makes excavation more complicated, with a sequence determined by the ground

conditions, although the intention is to remove the rock by roadheaders in three layers: top heading, bench and invert. In consideration of optimum roadheader operation and support requirements, the top heading and bench should be split into three drives each.

Similar to the running tunnels, the station support will include a layer of geotextile and pvc membrane of the primary support sprayed concrete. The total design thickness of the composite concrete support lining is 600mm.

Progress

Construction on Phase 1 of Line 3 started summer 2009 and the line is scheduled for public operation in 2012.

The daily advance rate achieved by the MT520 so far was only 3.5 to 4.5m due to limits on daytime operational hours only near the surface in this built-up area. ■

Below: Early face work for the MT520



Project summary

Project:	Bilbao Metro Linea 3 Phase 1
Client/developer:	ETS – Euskal Trenbide Sarea (Red Ferroviaria Vasca)
Finance:	Eusko Jauriaritza (Basque country government) and Bizkaiko Foru Aldundia (Biscay regional government)
Tunnelling & civils contractor 1:	UTE Metro Txurdinaga (JV of Altuna u Uria, Sacyr and Cavosa) for Txurdinaga to Casco Viejo
Tunnelling & civils contractor 2:	UTE Linea 3 (JV of Comsa, Cycasa and Nortunnel) for Etxebarri to Txurdinaga section – budget EUR 64.4M (USD 89.3M)
Technical assistance:	UTE Idom and Geoconsult III
Main excavation:	Sandvik MT520 (UTE Linea 3) and two Sandvik MT720 (UTE Metro Txurdinaga) roadheaders
Construction period:	Summer 2009 – 2012

1. DEFAULT SECTION

1. What percentage of tunnel projects require waterproofing?

- ☐ Under 10% ☐ 11-25% ☐ 26-50% ☐ 51-75% ☐ More than 76%

2. Is there a difference in the tunnel projects you work on between waterproofing and vapor intrusion protection?

- ☐ Yes - 2 Completely different approaches ☐ Yes - though we handle them nearly the same ☐ No

3. On tunnel projects, what waterproofing technologies has your firm utilised?

(You may select more than one)

- ☐ Spray applied (polyurethane, polyurea, other) ☐ Membrane (Bentonite)
☐ Membrane - Welded/Taped (PVC, Thermoplastic) ☐ Treated Shotcrete or Concrete ☐ Drainage only
☐ Other (please specify) _____

4. What type of waterproofing products are used for specific tunnelling methods (i.e. TBM or NATM or Cut and Cover)?

	TBM	NATM	Cut and Cover
Spray applied	☐	☐	☐
Membrane - Bentonite	☐	☐	☐
Membrane - PVC/Thermoplastic	☐	☐	☐
Treated - Shotcrete/Concrete	☐	☐	☐
Other	☐	☐	☐

5. Where are the causes of tunnel waterproofing breaches?

- ☐ Joints ☐ Membranes ☐ Applicator Error ☐ Material Selection ☐ Soil Contamination
☐ Other (please specify) _____

6. How does the type of tunnel work your firm does break out?

	Less than 10%	11-25%	26-50%	More than 51%
Sewer	☐	☐	☐	☐
Water	☐	☐	☐	☐
Rail	☐	☐	☐	☐
Automobile	☐	☐	☐	☐

Other (please specify) _____

7. In your area do water/sewer tunnels utilise:

	Water Retention Linings	Anti Corrosion Linings
Yes	☐	☐
No	☐	☐

8. What waterproofing technologies have been used on tunnel projects (all construction methods) successfully by your firm?

- ☐ Bentonite ☐ Thermoplastic/PVC liner ☐ Crystalline/Cement-based ☐ Spray Applied
☐ Other (please specify) _____

9. What methods have been use to address water ingress when a membrane or waterproofing system has been breached?

10. What role does the soil/ground type play in waterproofing product selection?

For instance, do soft soils utilise one technology over the other and hard soils similarly?

- ☐ Soil type is most important ☐ Soil type matters about 50% of the time ☐ Soil type has no impact on our waterproofing product selection
- ☐ Other (please specify) _____

11. When it comes to waterproofing your tunnel:

	Not Important	Somewhat Important	Important	Number One Priority
Cost of the Product	☐	☐	☐	☐
Total Installed Cost of the System	☐	☐	☐	☐
Warranty of Product	☐	☐	☐	☐
Warranty of the System	☐	☐	☐	☐

12. When thinking about waterproofing and tunnels - How Important is:

	Not Important	Somewhat Important	Important	Number One Priority
Waterproofing cost to the overall contract value of the project	☐	☐	☐	☐
Waterproofing warranty on tunnel projects	☐	☐	☐	☐
Approved Installer of Waterproofing	☐	☐	☐	☐
Manufacturer Supplied Engineering Support - Design Phase	☐	☐	☐	☐
Manufacturer Supplied Engineering Support - On Site	☐	☐	☐	☐

13. Who typically installs waterproofing products and systems on a tunnelling project?

- ☐ General Contractor ☐ Waterproofing Contractor ☐ Concrete Contractor
- ☐ Concrete Repair Contractor ☐ Manufacturer of Waterproofing ☐ speciality Contractor
- ☐ Other (please specify) _____

14. What is the single biggest challenge your firm faces when it comes to waterproofing a tunnel?

15. Could you please share a little bit about yourself?

This question is optional. If you provide your email we will provide you with updates a couple times per year on tunnel technology advancements. You may opt out at anytime. Thank you for your time today.

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Company: _____

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Livorno landfall

A string of micro-tunnel drives are being bored to protect the local environment as part of a project to import gas on the Italian coast near Livorno. Report by Patrick Reynolds

International energy markets in recent years have seen significant growth in shipments of liquefied natural gas (LNG) between countries. One of the latest LNG import projects is under construction in Italy, off the west coast near Livorno and Pisa, in Tuscany, where a fixed, offshore ship terminal is to be installed just over the horizon and linked to shore by a seabed pipeline.

The terminal is about 22.5km offshore and will allow LNG carriers to moor. The LNG will be offloaded into a fixed, converted vessel that functions as a floating storage regasification unit (FSRU). The unit will gently warm the LNG to change it from a liquid to a gaseous state for supply by a 32in (81.2cm) steel pipeline to shore and into the national distribution network.

But the onshore section has construction challenges that need to be overcome to ensure the environmental protection and minimum disturbance to water channels and flat environments of the vicinity. Design of the project turned to bored tunnels as the preferred solution to hold the gas pipeline, which will be installed and cemented into place.

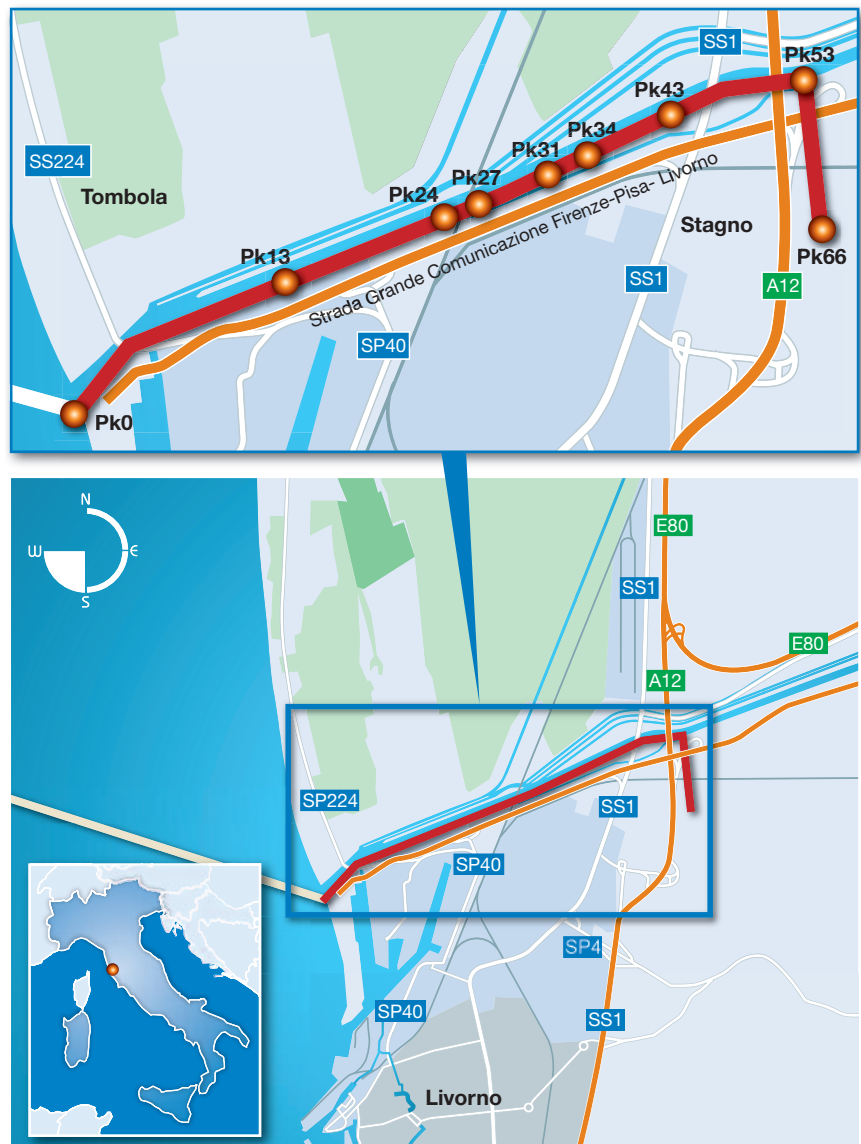
Denys is currently boring the run of tunnels, mostly between cofferdams in the edge of the main shallow channel. Four micro-tunnelling TBMs are being used and the excavations have been underway for a few months and are making good progress.

The entire project is to be completed and operational by mid-2011.

Project Development

The LNG project – the Offshore Tuscany Regasification scheme – is one of Italy's most important development in strategic procurement of natural gas supplies for the energy sector, and follows supply difficulties and energy peaks in winter in some recent years. The demand for gas is rising due to increased demand for gas-fired cogeneration, producing both electricity and heating water.

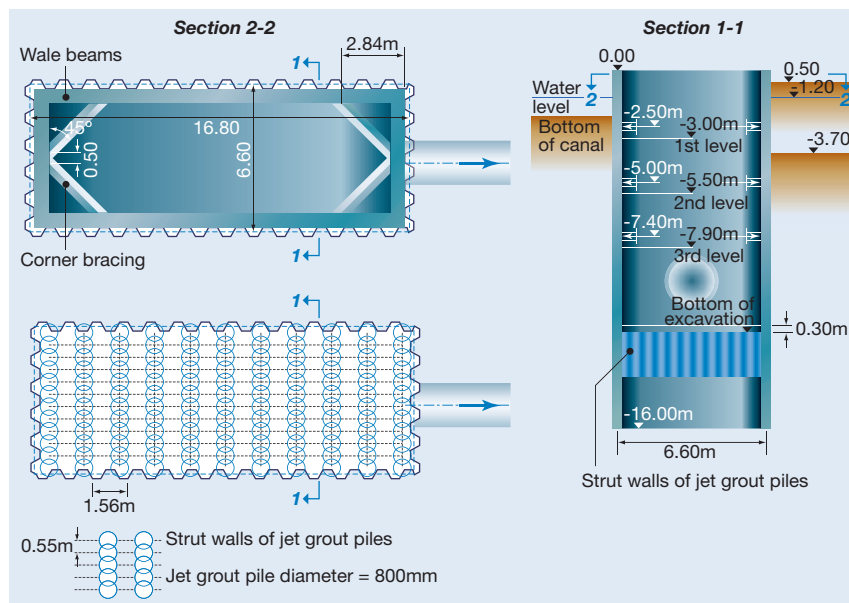
At full capacity, the scheme will be able to supply about 4 per cent of the country's annual demand and helps to also diversify



Above: Location of the micro-tunnelling project that is part of a pipeline project to bring gas supplied onshore near Livorno, Italy

the ownership of the energy infrastructure and increase competition. Italy has two other regasification terminals, at La Spezia and Rovigo. Aside from the offshore LNG project, further regasification facilities are to be built in the country to help LNG supply about a third of the country's natural gas.

Permits to build and operate the regasification terminal are held by Offshore LNG Toscana (OLT), which is a dedicated project company established by a consortium of energy and industrial groups—Iren (46.79 per cent), E.ON (46.79 per cent), OLT Energy Toscana (3.73 per



Above: Plan and cross-section of a typical launch shaft in the canal for the micro-tunnelling works

cent), which originally conceived the project, and Golar LNG (2.69 per cent).

The special purpose company plans to invest more than EUR 600M (USD 840M) in the scheme, which could see each LNG carrier shipping up to about 130,000m³—equivalent to approximately 80Mm³ of gas—or slightly more.

LNG does not dissolve in water and evaporates on contact without mixing or leaving residue or polluting. Neither is there residue remaining from any spillage onto the ground.

The project site was selected to be near Livorno for two reasons—good port facilities to support the offshore infrastructure, and the area is also close to some demand centres and so also grid connections.

Preparations for the project began in 2003 with the scheme being proposed and

followed by the first step in the approval process. In 2004, the regional council and national government approved the environmental impact status. Approvals for construction of the project came in late 2005 to early 2006, and some months afterward the authorisation for the onshore gas pipeline in Tuscany was secured.

Construction activity on the project began in 2007 with some preparatory activities and the following year the project moved ahead to acquire two key assets—the gas carrier ship (“Golar Frost”) that would be converted into a floating offshore regasification terminal and for occupation of the specified fixed area of the Mediterranean Sea for the refitted ship. The following year the permits came for laying the pipeline both offshore and onshore.

The six-year-old Golar Frost was

fabricated by Hyundai Heavy Industries and is being converted in dry dock in Dubai.

Offshore works commenced in February this year with the Castoro 7 pipe-laying barge to bring the 29.5km long pipeline to shore by the end of the following month. Preparatory activities for the tunnelling works to hold the 6.5km long onshore section of the gas pipeline commenced a year ago.

Onshore Works

While OLT signed a contract with Saipem to install the offshore works of the fixed point mooring terminal and pipeline, it agreed a separate deal to construct the onshore section with Snam Rete Gas, an Italian gas distribution, storage and regasification company, and part of the energy group Eni.

The onshore section of the project calls for about 5km of construction below the floodway channel of the River Arno and the remaining 2km on dry land. The pipeline is being buried at a minimum depth of almost 2m, and at least 6m below the floodway to guarantee navigability.

A number of alternative solutions were considered for the onshore works to bury the 800mm gas pipeline. The first option examined was for a continuous cut and cover open excavation that would run next to the channel but the option was dismissed for reasons to do with permit and environmental approvals.

A variation on the proposal had the alignment in the channel with sheet-piled excavations allowing for the cut and cover construction over a total length of 7km. However, again for environmental reasons and potential pollution from disturbing the bed of the channel led to the rejection of this option.

The third option for burying the pipeline was to use directional drilling but this was dismissed for technical reasons—the polluted bottom of the channel would have to be pierced numerous times for the drives, and there was the risk of potential blow-outs from below the channel bed. A further block on this alternative was that there was insufficient holding space for the pipeline before it could be pulled-in to a bore done by directional drilling.

Finally, it was established that micro-tunnelling, as a later suggested possibility, would be the most effective and acceptable approach. Micro-tunnelling was seen as requiring fewer construction sites along the alignment and consequently less excavation through the polluted channel bed and also it offers better control of the front pressure at the face would reduce blow-out risk.

Below: Denys is using four Herrenknecht AVNs on the micro-tunnelling contract





A joint venture between Denys and Max Streicher is undertaking the onshore tunnelling and pipeline works for Snam Rete Gas under a lump sum contract valued at around EUR 40M (USD 56M), which was awarded in September 2009. The construction programme runs to mid-2011.

Denys is mainly responsible for the micro-tunnelling while Streicher is focused on the construction shafts, pulling-in the steel pipeline and mechanical works, such as welding on the pipe.

The client is represented on the project by Italian oil & gas and energy sector consultant Enereco.

Tunnel

Denys is constructing 5km of tunnel below the floodway using micro-tunnelling for a succession of drives of varied lengths, and the tunnels are also of varying diameters to house the 800mm steel pipeline to carry the gas.

The tunnel construction comprises:

- Two drives of 1170m length for concrete tunnel pipes of 2000mm i.d. (2400mm o.d.)
- Two drives of 900m lengths for tunnels of 1800mm i.d. (2160mm o.d.)
- A drive of 430m long for a tunnel of 1800mm i.d. (2160mm o.d.)
- A drive of 450m long for a tunnel of 1600mm i.d. (1960mm o.d.)

Geology along the tunnel alignment, below the floodway canal, comprises soft soil mainly fine sand overlying clay with organic material, although there is a short section where the bore will pass through lime with mica.

The eastern section of the alignment, the furthest inland, is mainly through fine sand while the sections of tunnel closer to shore will be bored through clay with organics mainly, the upper part of the face meeting the fine sand above.

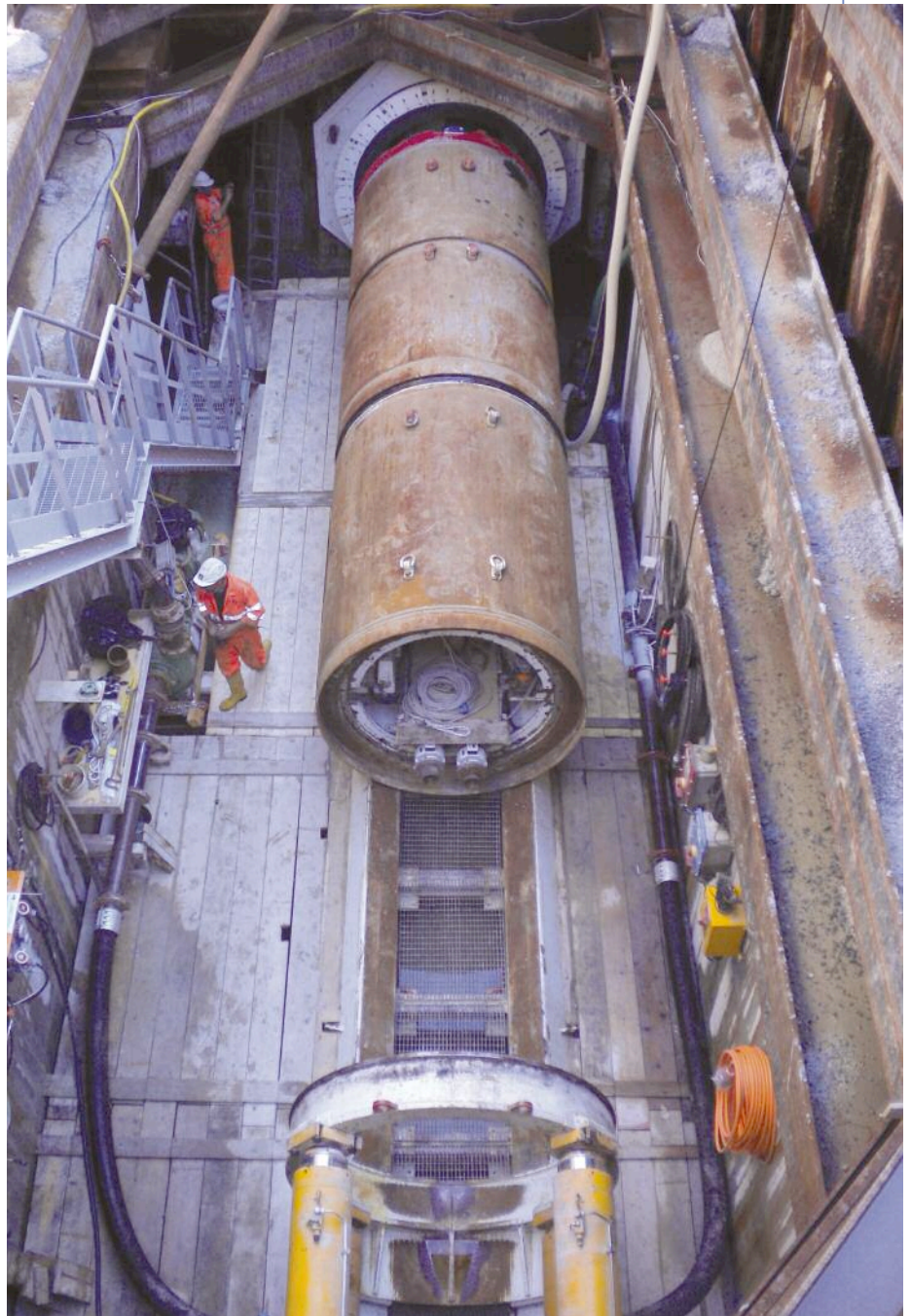
Groundwater level in the mostly permeable soil is at the surface level of the channel, itself generally 1m deep, and so the head of water over the tunnel is 7m.

Key aspects of preparation for the tunnelling works included the planning and security aspects, and site investigation.

The key people Denys has on the micro-tunnelling contract are: Geert De Wilde, senior project manager; Nicolas Solda, chief project manager and Dirk Derycke, division manager for tunnelling.

Micro-tunnelling

Excavation in the tunnelling works are being performed by four slurry shield TBMs, all Herrenknecht AVNs and each with three or four parts and the concrete



Above: TBM launch on a 880m long, 1,800mm i.d. drive from shaft P43 in September

pipes for the tunnels are being pipe-jacked into position behind them. Denys owned three of the shields and also bought a new TBM for the job.

The tunnelling works call for a number of sheet-piled and braced cofferdams with jet-grouted wall-strips in the foundations as lower struts. The concrete base slab is the working platform for the construction activities.

Shafts are constructed by sheet-piling from a pontoon near the side of the 60m-

wide channel, staged excavation and then jet grouting in the bottom before pouring the concrete base slab. The cement columns are 800mm diameter and overlap at 550mm centres and each jet-grouted line is spaced at 1.56m centres.

Six starting shafts for the TBMs are to be used on the project, each 16m long by 5m wide by 10m deep. There are also three reception shafts, which are 8m by 5m by 10m, or half the size on plan as the starting shafts.



Tunnelling works started in June, and the early drives are three stretches at opposite ends of the tunnel layout:

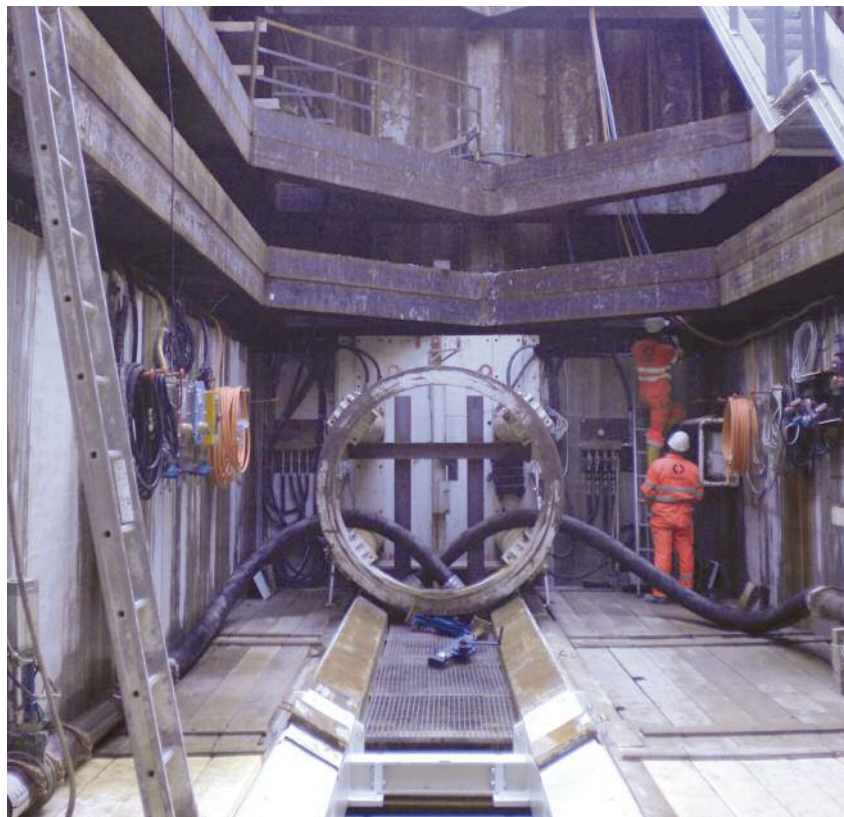
- One of the two 1,170m long, 2,000mm i.d. stretches—the section nearest the sea, between shafts marked P0-P13. It was the first drive and completed between early June and mid-August.
- At the opposite end of the layout, the 450m long, 1,600mm i.d. drive between P66-P53, which was completed in late September.
- Coming from the opposite direction to P53, the 880m long, 1,800mm i.d. drive from P43 which started last month.

The remaining drives will work progressively towards the middle of the tunnel layout and construction of the next two starting shafts, P34 and P24, have been completed. The final drive is expected to be finished in March next year.

The shields are guided by a VMT automatic laser system. While that focus is traditional for tunnel, a separate vertical measurement focus at the starting shafts is also important to ensure that, should the water level in the channel rise drastically, the tunnels can be sealed off. For that purpose a pre-constructed cap is ready, should it be required.

Bentonite is used for the pipe-jacking of the concrete pipes with an automatic lubrication system. An additive was used to counter the salt water conditions. The mix design of the concrete pipes, manufactured by local firm ILCEV, is matched to the marine environment. The pushing capacity of the pipes vary as follows:

- Concrete pipes 2,000mm i.d. (2,400mm o.d.) – 1,000t



Above: The drives in the west end are mainly through clay, those in the east are mostly in fine sand and the head is 7m of water

- Concrete pipes 1,800mm i.d. (2,160mm o.d.) – 900t
- Concrete pipes 1,600mm i.d. (1,960mm o.d.) – 800t

The quantities and application of the lubrications depends on the soil, and the performance is judged by the jacking forces

required during pipe placement. The tunnelling works use intermediate jacking stations—one every 140m, approximately, and are located between two specially-fabricated concrete pipes. Nine pipes are installed in the longest drives.

The average advance rate achieved is 20m in 24 hours, based on the long first drive over the summer, says Denys.

Ventilation is provided when drives reach a distance of 300m or before should it be required. A Korfmann-manufactured fan is placed in the launch shaft and a 200mm flexible hose in the pipe.

Spoil removal is by slurry pumps. The contractor is using desanding units reinforced with filterpresses where necessary. The filterpresses are located at the three launch shafts in the section of tunnel with clay along the alignment—the half of the job to the west, nearest the coast.

In total, the excavated material from the bores, shafts and trenches will be approximately 35,000m³— including the last leg of the onshore section, furthest inland. At the end of the micro-tunnelling stretch, this final 2km long section will have the gas pipeline buried at a depth of 1.8m by placing in shallow trench excavation. ■

Below: Intermediate jacking points are placed every 140m along the drives



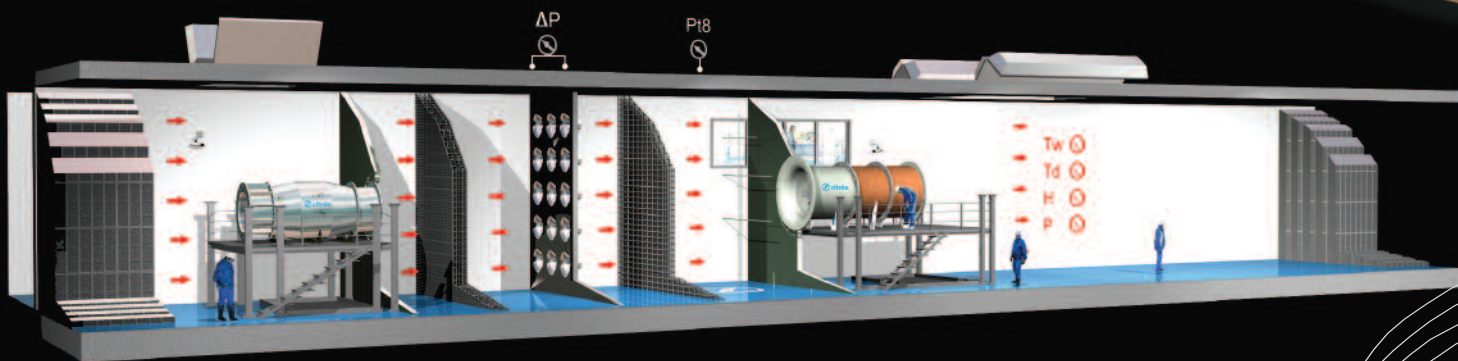
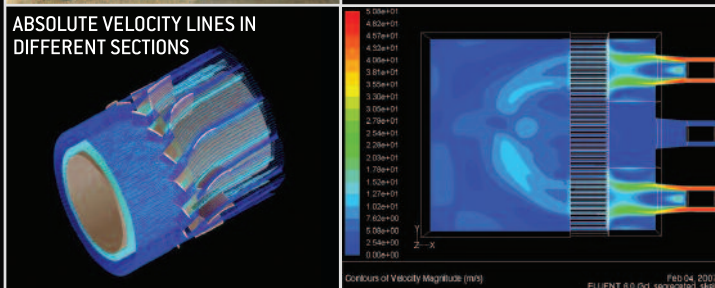
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Saving the tunnel customer

Although passing through tunnels is statistically one of the safest means of transport, major incidents have given the impression of wider potential danger. The aftermath of the Mont Blanc Tunnel fire and tunnel safety surveys have highlighted real areas of concern. Much of the subsequent attention has been on protecting tunnel structure by so-called 'passive' means, but humanitarian concerns must be focused on the speed of getting travellers away from the hazardous areas as soon as possible, for the dangers to life work much more quickly than dangers to structure. Maurice Jones reviews some best practice and developments to improve the chances of survival

Speed and location are vital factors in surviving a tunnel fire, or indeed any other hazardous incident. There are many factors involved in improving the chances of surviving an incident and, as surveys have shown, widely varying conditions and facilities in existing tunnels. The European Tunnel Safety Directive of 2004 placed safety requirements on all new tunnels over 500m and situated on the TENs (Trans-European Network) highways to be complied with by 2014. The same requirements must be met by upgrading existing tunnels by 2019. The moves have also shamed operators of major tunnels not on the TENs network into upgrading their safety provisions.

Another result of the major fires has been a proliferation of study groups, both national and international, working on the nature of transport tunnel fires, the best

Below: Two-way flow in road tunnels may be cheaper but can be inherently hazardous especially if traffic flows are high. Photo of Piqueras Tunnel from the FIA (Federation Internationale de l'Automobile), which is concerned about slow progress by some countries in meeting EU Tunnel Safety Directive deadlines



means of emergency organisation and rescue, active fire protection and the correct means of ventilation control. Opinions still vary substantially on correct approaches, particularly in ventilation and fire protection, although a consensus is being approached gradually.

Some of the important factors for survival are:

- Traffic density. Many tunnels carry much more traffic than for which they were designed. Increased density means driving closer to an incident;
- Rapid detection and location of fires and other incidents;
- Efficient communications with tunnel users and emergency services;
- Active fire suppression (and fighting) systems;
- An effective plan for controlling ventilation the direction and flow of ventilation to remove smoke, fumes and flames from as many tunnel users as possible;
- Maintenance of power supply to services required in an emergency as long as possible;
- Proximity of fire-fighting and rescue services base, with suitable equipment to

rescue tunnel users;

- Clearly indicated route to escape passages or refuges, plus obvious alarm and communications stations;
- Construction of refuges and escape routes to maintain integrity as long as possible. If feasible there should be a bias towards secure escape passages away from the affected tunnel bore rather than refuges;
- Availability of 'fresh' air supply to emergency refuges and escape routes.

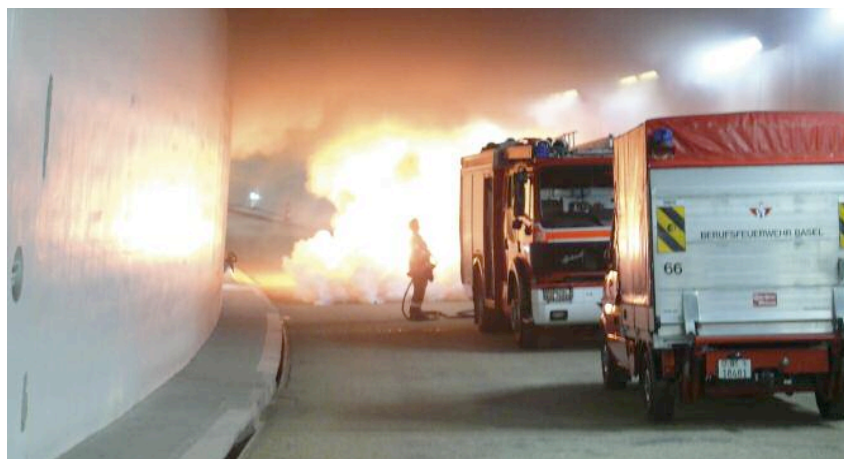
Although correct ventilation control is a vital function in aiding fire control and preserving life, this will be covered by a technical review in the December issue of T&TI, as it is a complex subject in its own right.

This article will cover some of these important topics such as fire and incident detection and location, new developments in active fire protection, clear escape and safety information, refuges and escape route construction.

Detection

Investigations into the Mont Blanc Tunnel fire found that not only were most detection systems poorly maintained, but

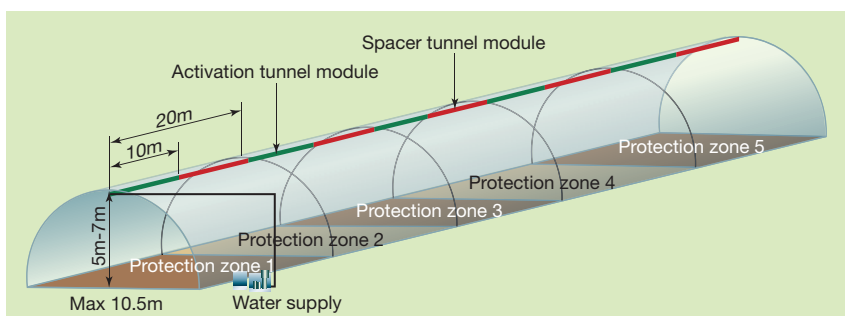
Below: A test fire in a road tunnel. Note smoke layering [Photo: HBI Haerter]





Left, top: Smoke emerging from the Veliki Glozac Tunnel in Croatia during testing of Lios Technology's fibre-optic linear heat detection system

Left, bottom: Figure 1 – Diagram of VID fire-kill from Denmark



they also had design deficiencies. These included delays in sensing fires from moving vehicles (French end), and frequent false alarms (Italian end). An obscuration meter worked but a heat detector alarm was delayed. When the French alarm was set off and the tunnel closed in nine minutes, the fire had already reached 1,000°C. It is therefore vital for detection and alarm systems to work as quickly as possible to give tunnel users a chance of escape, particularly if they are not directly aware of the fire. Most victims stayed in their vehicles and were killed within 15 minutes of the fire being detected.

These days the preference is for continuous, reliable, heat detection systems, of which there are many available, together with frequent video incident detection units. Even so, moving vehicles make a fire or smoke more difficult to detect. Securiton's SecuriSens TSC 515 temperature sensing cable has been described before in T&T but briefly comprises an encapsulated acquisition and bus system linking small temperature sensors at regular intervals in the sheathed ribbon cable. Evaluation logic in a data processor scanning the

sensors determines when to report an alarm or a fault to a computer or fire alarm control panel.

Securiton also supplies video-based fire detection based on the digitisation and analysis of video signals from surveillance cameras. Using special algorithms the presence of smoke or fire in the image can be determined and the difference between them. This is accurate enough to link with set levels of pre-alarm or full alarms. Such a system should be used to complement and confirm other fire and smoke detection systems since there are no standards or test specifications for such systems yet says Securiton.

Active fire protection

Rather than wait for fire-fighting teams to arrive, automatic fire suppression systems offer a major advance in tackling fires in the vital early minutes. Conventional spray barriers have been tried, but it appears that water mist systems offer the greatest potential due to the greater cooling capacity of the smaller droplets and the lower water volume requirements.

The high velocity Marioff Hi-Fog system is the subject of a separate article in this issue of T&T. Fellow UTC Fire & Security

company Silvani Anticendi also supplies a patented fire extinguishing system for road tunnels in the Italian market.

The Fogtec system from Germany is widely used on railway locos and rolling stock, but has also been selected by Eurotunnel as part of the fire fighting safety upgrade. Fogtec is part of a consortium also including Rodio J (fire sprinklers), ACIS, and contractors Eiffage and Spie. Efectis carried out a prior fire protection analysis, and Resirep is carrying out the civils work. Since November last year the consortium has been working on the new SAFE fire fighting stations in the tunnel and carried out a full-scale test in Spain last April with fire loads of over 200MW to simulate a 40-car freight shuttle train fire. Fogtec says that the tests demonstrated the ability of the water mist to contain a fire and limit its propagation.

Eurotunnel is understood to be the first railway tunnel to be equipped with a similar system. Before specification and expert group carried out a quantitative risk assessment and cost-benefit analysis, which indicated that potential savings in the fire-fighting system would exceed investment costs significantly.

Fogtec is also being installed in the New Tyne Crossing road tunnel by TT2, as well as the existing tunnel, with fire protection consulting by Halcrow. The contract was awarded to Fogtec by the main contractor Bouygues Travaux Publics UK. In the design the tunnels are split into 130, 25m-long sections. In the event of a fire, Fogtec in three adjacent sections will be triggered simultaneously.

Another automatic fire suppression supplier, VID fire-kill of Denmark, also carried out full-scale tests last year. Its Turprotec system is a low-pressure (10-bar) water mist which, in the test, is split into 20m-long sections (Figure 1) operating from the tunnel centre line in the crown. The diesel pool and solid class A fire tests simulated vehicle fires with heat outputs up to 100MW. In conjunction with Entreprise Bane, also of Denmark, VID Fire-Kill used the abandoned Runehammer tunnel in western Norway. This is 9m wide, 6m high and 1600m long with two carriageways. The Sintef laboratory carried out the tests themselves. In addition to the cooling effects of the water mist, it was observed that the system prevented smoke

backflow in tunnel air velocities down to 2m/s.

The way out

Tunnel designers cannot expect tunnel users to react to an emergency in an entirely rational way, but the best compromise must be found to encourage them to act in as calm a manner as possible to maximise the chance of survival. The situation will be particularly difficult where large crowds are involved, such as in situations like the London King's Cross fire, or evacuations of long trains in tunnels. Several consultations such as Pöyry and Mott MacDonald have developed crowd simulation procedures to check the designs of stations and tunnel escape routes, including likely some extraction routes. Pöyry also carries out risk assessments of safety measures to evaluate their usefulness specific to projects.

Advising tunnel users—who are unlikely to be familiar with the 'behind the scenes' layout—of the best way out is not an easy matter in a smoky fire, especially when those people may be panicking. As the heroic security biker of the Mont Blanc Tunnel fire, Pierluccio Tinazzi, advised those he saved to stay low and close to the tunnel wall in order to maintain direction and keep below the hot smoke. However, this is generally not the best place to see normal signage and find exit routes. Therefore communications to escapes, whether over audible means or by signage, has to take this into consideration with clear instructions not only to give correct information but also to inspire confidence and calm.

Low-level direction indicators with either

emergency power lighting or luminous graphics can help self-rescue in difficult circumstances. Jalite produces a range of graphic signs in different forms according to ISO 7010:2003 standard, and using photoluminescent materials to comply with the requirement for lit signs at all material times. As well as the use of the standard 'running man through door' symbol, plus arrows, the ISO Standard and sign range includes standard symbols for emergency door opening, and for the location of automated external defibrillators and emergency escape breathing devices as specified for marine vessels.

Jalite developed a special range for tunnels (Jalite 316 LLL) to comply with materials restrictions for low smoke, zero halogen (LSZH) generation. Included is a seamless guidance router marker within a stainless-steel angled profile with an encapsulated photoluminescent layer. The system is set for installation in two major UK tunnels.

Ideally fire and rescue teams are able to reach tunnel users in time and permanently stationed teams at or near major tunnels facilitate this. The teams will be equipped with items such as thermal imaging cameras, mask- or helmet-integrated communications systems and long-period breathing apparatus. They can also bring breathing equipment and medical assistance to assist escapees, although these will require professional training.

Non-specialist tunnel staff may be able to assist with less specialised equipment such as Dräger's Oxy K pro breathing apparatus. Although this still requires some training, it is simple in operation and is

intended for use for oxygen supply where smoke, toxic gases or lack of oxygen is present. A mask protects the face and eyes against smoke and heat. Each unit lasts for 30 minutes with immediate oxygen on starting and an approximate 20-minutes-elapsed warning.

However, with a rapidly developing fire sufficiently quick response to aid rescue seems unlikely in most cases. It is therefore left to the tunnel users themselves to find their way to a safe refuge or escape route with or without external assistance.

Refuge and escape

Passive fire protection is promoted mainly to protect tunnel structures from the damaging effects of the high temperatures developed in tunnel fires, especially from freight traffic. The EU Uptun project has demonstrated that typical tunnel fire temperatures in a road tunnel can range from 480°C for a car fire to 1400°C for a large petrol tanker fire. Many test programmes have been undertaken to study tunnel fire characteristics, one result of which is the drawing up of graphs to show typical temperature development over time. Of these, the RWS curve from Netherlands test results is generally considered the most 'severe' and now most widely used to test fire protection systems.

The main danger to life is usually from toxic smoke and fume inhalation and this can occur much sooner than any danger of structural collapse. The classic reference point has become the Mont Blanc where it was found that co-ordination of services and control from both ends and safety precautions were inadequate and traffic density was too high for the tunnel conditions. After the subsequent enquiry it was decided to improve safety under one managing entity, including an increase in the frequency and quality of refuge facilities although there is still no separate escape route except through ducts within the single-bore main tunnel structure.

Much depends on the location and movements of any fire. It is important that tunnel escapees can reach a non-toxic atmosphere as soon as possible. Therefore, passive fire protection will still have a role to play in the construction of temporary refuges (pending rescue). The same may be true for escape passages in case high temperatures pass through the route before escapees use them. A particular source of vulnerability is where reinforced precast concrete is used to create separate cable and ventilation ducts and/or escape passages, as these could

It's behind you

As part of the drive for better fire and rescue facilities in the Mont Blanc Tunnel, BAI (Brescia Anticendi International) developed this Janus fire tender—so called because it can 'look' both ways. It is part of the permanent fire brigade set up in three locations. The unusual vehicle is also better at manoeuvring and reversing in the tunnel. Built on a MAN chassis, it has 4-wheel steering, a 4000-litre water tank and 500 litre of fire-fighting foam. It also has infrared cameras for use in darkness and/or smoke. Both cabs are pressurised against smoke ingress. There are special fire self-protection systems for both cabins and wheels.



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Far left: Mesh is fixed to the main lining with 'pig tail' anchors before applying FireBarrier 135

Left: Applying Thermal Ceramics FireBarrier 135 through steel mesh

collapse in high temperatures, preventing escapes and producing uncontrolled spread of toxic materials.

A wide range of passive protection products is available split, generally, into sprayed-on materials and prefabricated panels.

FireMaster FireBarrier 135 from Thermal Ceramics is a refractory cement material that can spray applied in a single layer, normally over steel mesh, or installed as precast sheets. It can withstand temperatures up to 1350°C for long cycle times says Thermal Ceramics. Based on comparative tests of fire protection materials in 2005 under the Uptun project, FireBarrier 135 is claimed to produce the lowest lining temperature of the six products tested. The tests were carried out in the Virgolo Tunnel, Italy, with a 30-MW simulated tanker fire.

In normal tunnel use, passive protections must again be resistant to the possible ravages of cleaning and spray from vehicles and the road surface, as well as firefighting in an emergency. FireMaster FireBarrier 135 has undergone laboratory tests at the TNO in the Netherlands to

prove its resistance to high-pressure spraying. On application it can be finished with hand towelling to provide a suitable surface for painting or attaching signs, thus avoiding cladding.

FireBarrier 135 was used in the construction of the new refuges in the Mont Blanc Tunnel to comply with the duration requirements of HCM and ISO fire curves at two hours and four hours respectively. 1700sqm of surfaces were treated with FireBarrier 135 using 110t.

BASF Meyco's Fireshield 1350 is another spray-applied insulation material to prevent heat from damaging concrete and its steel reinforcement. Meyco says it is able to withstand dynamic and collision loads in the tunnel and is compatible with all cleaning and maintenance methods. As it is a cementitious mix it can be spray applied like normal shotcrete using robotic systems for larger requirements. Tunnel applications have included protection of escape tunnels in Athens.

Ventilation control may not be the only way of keeping smoke away from tunnel users. About two years ago Beijing Yingtelai Morgan Thermal Ceramics Textiles (YMTT)

completed the supply and installation of smokeproof curtains for lines 5 and 10 of the Beijing Metro in time for the Olympics. The curtains have also been specified for subsequent metro lines in Beijing. The curtains can be handled in three modes for easy operation. The curtains, which were invented in 2000 by YMTT, have also been exported to Europe, Japan, Singapore, Taiwan and the US.

Promat (Etex Group) fire-resistant panels have been installed in many tunnels since the Dartford Tunnel in 1963 and the Elbetunnel in 1975. Latest applications include the Schidetunnel (Limburg) and Theatertunnel (Frankfurt-am-Main), also German road tunnels.

A speciality of Dräger is the design and construction of fully-equipped refuge chambers, such as in ISO standard containers. Designed primarily for construction and mining works, they could also be used for more permanent installations, serving either as an intermediate rest station or to house escapees until rescued. The chamber is activated by an alarm and can operate for up to eight hours or 48 hours, depending on the designed function.

For more mobile needs Dräger also designs rescue trains equipped according to customer requirements. The trains carry containers for the fire and rescue crew, fire fighting equipment and evacuees. The containers can be hermetically sealed off from the contaminated atmosphere with air supplied from reservoirs and recycled. Crew and escapees can spend hours in the containers without masks. Smoke contamination during transfers is minimised by positive pressure ventilation, air locks, smoke extractors and a multi-stage smoke retention system. Even if the outside is masked by dark smoke, supervisors can use monitoring devices, communications and thermal imaging cameras to check on conditions outside. The equipment can also include quick-filling systems for professional respiratory equipment, thus maximising operational time and cutting the need for frequent returns to the 'surface'. Customers for such technology include the Austrian Federal Rail Company (ÖBB), the Swiss rail companies SBB, BLS and RhB and the Deutsche Bahn (DB). ■

Below, left: A portable refuge station for respite from escaping the tunnel from Dräger. Similar refuges could be built into a tunnel

Below, right: Dräger fire and rescue trains can be equipped according to customer wishes

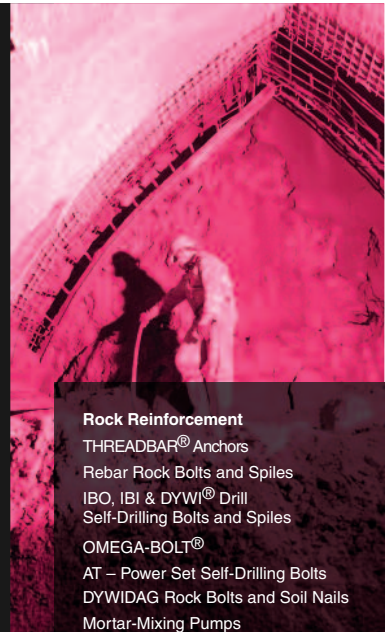


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High pressure mist for fire suppression



Fire is always a serious threat to transportation infrastructure and traffic continuity. Fires in confined underground spaces such as road tunnels and metro stations are particularly dangerous because they can grow extremely quickly, generating very high temperatures and amplifying the dangers posed by fuel spills and toxic smoke. These phenomena can, in certain circumstances, kill people who are just a few metres away from an escape route during a fire. They can also prevent emergency services from approaching a fire to fight it. Pasi Vuolle, tunnels global business development manager at Marioff gives this report on the use of the firm's high pressure water mist system

Traditionally, most tunnels are protected against fire by passive safety measures. The term "passive" refers to the use of construction materials that inhibit the spread of fire and safety structures such as special escape tunnels, emergency exits to a neighbouring tunnel or to the surface, and spaces where people can find shelter. Passive safety measures contribute to underground safety in important ways, but can prove insufficient during major fires such as those that occurred in the Mont-Blanc and Gothard tunnels.

In the search for solutions that better mitigate the threat of underground fire, experience drawn from fire testing and field

installations shows that high-pressure water mist technology is an excellent solution for preventing direct and consequential damage to people, tunnel infrastructure and traffic. Therefore an increasing number of high-pressure water mist systems are being installed around the world and working to protect underground transportation infrastructure such as road tunnels. In this environment water mist systems beat down fire instantly upon activation, suppressing and controlling it before it can spread, using minimal amounts of water.

As the world's leading supplier of water mist systems for fire protection, Marioff has delivered a number of HI-FOG® Water Mist Fire Protection Systems to operators of

Above: Hi-Fog uses plain water and is therefore environmentally safe. The system uses substantially less water than conventional deluge systems, a great advantage in underground environments where water supply can be problematic

underground facilities. As a result of full-scale fire testing of the system in the tunnel environment, these forward-looking organizations were convinced by HI-FOG's ability to provide excellent fire protection with minimal water discharge.

A86 Paris

The A86 West tunnel in Paris, protected by a high-pressure water mist system, is

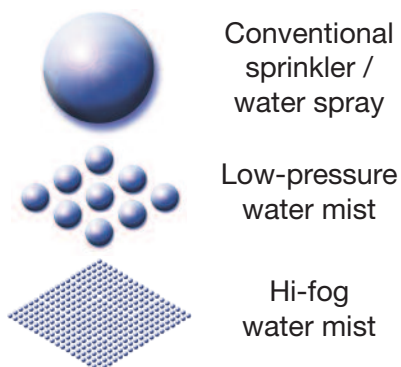


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Typical drop size range (mm)	Number of droplets per litre of water	Surface area (m ²)
1...5	15 thousand to 2 million	1...6
0.2...1	2 million to 250 million	6...30
0.025...0.2	250 million to 150 billion <i>Superior cooling and local inerting</i>	30...250 <i>Superior blocking of radiant heat</i>

Above: The smaller the water droplet, the greater the surface area of the water in the volume of space and the greater the system's fire fighting effectiveness. Hi_Fog water mist attacks two of the three things that fire needs to grow;

Right: Protected by the world's largest high-pressure water mist system the A86 West tunnel in Paris is a model of tunnel safety



probably the world's largest tunnel protected by an active fire protection system. This tunnel is a feat of engineering and design at 10 km long with two superimposed levels, one in each direction. Each level has two traffic lanes and a hard shoulder. Reserved for light vehicles, the tunnel is equipped with all the latest safety devices, exceeding the requirements of new French regulations governing tunnel safety.

Front-line fire protection is provided by a high-pressure water mist system with the following mission in case of fire: reduce the ambient temperature, facilitating the evacuation of motorists to the emergency exits located at 200-metre intervals;

meanwhile, moderate conditions for the emergency services arriving on the scene, allowing them to contain, control and extinguish the fire.

The importance of fire protection is magnified in this type of tunnel, designed to carry very dense traffic. The ceilings are very low: it may be difficult to evacuate even small quantities of smoke. The heat given off by a fire will also quickly affect the low-lying ceiling equipment.

The A86 West water mist system carries out its mission with 24 spray heads per coverage zone, each 33 meters long. The design calls for three zones to trigger simultaneously in order to cover an area

about 100 m long around the seat of a fire. HI-FOG® micro-droplets rapidly absorb heat, particularly by evaporation, giving very effective cooling. They greatly reduce the amount of smoke a fire gives off, by limiting the development of its heat intensity. This contributes to safe evacuation and saves lives during the first critical seconds and minutes of a tunnel fire.

M30 Madrid

The Madrid M30 project is the world's largest urban tunnel project, involving 99km of new road construction with 56km comprising tunnels. The project covers the redesign, rerouting and refurbishing of the inner ring road of the city of Madrid. Over a number of phases the M30 project has been rerouting major sections of the road through new tunnels, freeing up surface areas for redevelopment into green areas, footpaths, bicycle paths and new housing while significantly reducing inter-city travel times.

In the project planning phase, seven tunnel segments were identified as requiring an active fire protection system. A number of different water mist systems were subject to full-scale fire testing. The results convinced the road authority that it



Left: Hi-Fog spray head for tunnel fire protection, with assembly body and protective cap



Above, left: Image 5: Hi-Fog spray head system installed in roundabouts in Helsinki service tunnel;

Above, left: A full-scale tunnel fire test carried out for the M30 Madrid tunnel project



their fire hoses. Furthermore, experience gathered from full-scale tunnel fire tests showed that the velocity of the longitudinal ventilation during a water mist discharge can be less than when water mist is not being discharged. This helps the fire brigade approach the fire scene safely from the upstream side – they will not be impeded by a loss of visibility.

A general fire protection principle governing this type of project requires all water used to fight fire to be collected in a separate collection reservoir. This is also a clear cost-cutting benefit of Hi-Fog compared to the more water consuming conventional deluge systems.

The climate in Finland can be extreme cold during the winter and therefore a thermal protection is needed for the water mist system piping: a trace heating system was installed for the main tubes affected by low temperatures. Roads in Finland are treated with salt to prevent icing in temperatures just below zero. All the pipes and components are made of high-grade stainless steel grades in order to give the best protection against corrosion in aggressive tunnel environments. This will naturally prolong the life-time of the water mist system. Marioff's high pressure water mist technology combined with professional service presented the most economical solution for the Helsinki service tunnel.

System testing during the commissioning was carried out in order to ensure seamless interaction with other safety systems. Training of operating personnel and the local fire brigade were included to Marioff's turn-key delivery in the Helsinki Service tunnel project.

Worldwide effort

Improving safety in underground infrastructure is a worldwide effort bringing together scientific research, governmental authority and private sector business. As the commercial proponent of a significant technology for underground safety, high-pressure water mist as exemplified by Hi-Fog, Marioff has carried out an intensive program of R&D and full-scale fire testing of the system in the tunnel environment. As a result, type approvals for the system performance in this environment have been granted by a number of leading authorities regulating tunnel safety. ■

was possible to design and build a water mist system to handle the M30's extra-wide tunnel sections and potentially large fire loads (HGVs) while using modest amounts of water compared to traditional deluge systems. The seven tunnel segments designated as requiring active fire protection are now protected by water mist systems.

Helsinki service tunnel

The Helsinki service tunnel was built in 2007-2009 and is protected by Finland's first automatic tunnel fire protection system. The total length of this tunnel is 2 km and it connects several commercial centres of the city and e.g. the University of Helsinki including their parking facilities and service tunnels. Service tunnel will allow city to expand its pedestrian zones by guiding especially the service traffic into the tunnel.

The average height of the tunnel is 5.5 metres and the width varies from 7 m to 20 m. The tunnel also contains 4 roundabouts of different dimensions. It was a considerable technical challenge to implement the water mist system zone

sizing taking the roundabouts into account while maintaining the required performance together with the ventilation and fire detection systems.

The water mist system is designed to discharge over two 25m long zones simultaneously. The system flow rate is secured by three large pump units driven by diesel engines. The flow rate of each pump is 1200l/min; two of them are required to operate simultaneously with the third designated as the back-up unit. The back-up pump unit can be deployed to add flow rate, covering larger areas if needed. Water for the water mist system pumps is supplied from two separate sources: a main city sprinkler feed and a water reservoir located close to the high-pressure pumps. The water is fed from the water reservoir by a diesel pump unit for one hour of operating time.

Water mist's excellent cooling capability is considered to be an essential advantage. It is notable in tunnels that, if there is no fire suppression system to provide cooling, fire fighters cannot approach the fire close enough to fight the fire effectively using

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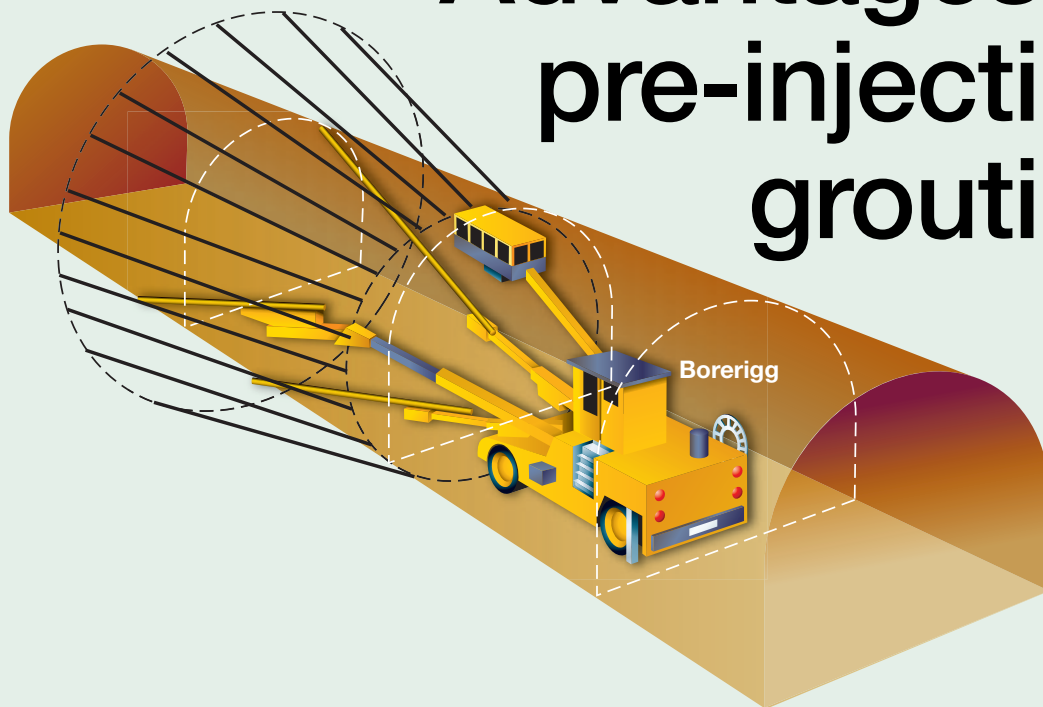
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Advantages of pre-injection grouting



The pre-injection method, or injections ahead of the excavation face in underground construction can in many situations offer significant advantages, particularly in difficult ground conditions like water ingress or mechanically poor ground or soil. K. G. Holter and H. O. Hognestad of BASF Meyco look at the use of modern cost-effective methods and material technology for pre-injections in shallow tunnels

Collapses at the tunnel face or unexpected high water intrusions are not uncommon experiences when tunnelling in geologically difficult ground like fault zones in alpine terrain or tunnels with shallow location influenced by weathering or low rock stresses. Tunnelling in urban areas often involves shallow location of tunnels, proximity to existing underground structures, as well as establishing connections between these structures. The consequences of a groundwater drawdown or deformations in the ground caused by instabilities are particularly unacceptable due to the possible impact on buildings with sensitive foundations.

Pre-injections in shallow located tunnels can strongly reduce the risk of mishaps. The state-of-the-art technology within rapid hardening microcements and liquid colloidal silica is particularly emphasised. This technology can improve the cost

effectiveness and technical feasibility of tunnelling in a sensitive environment in difficult ground significantly.

The recent improvement of the pre-injection technology employing controlled accelerated setting of microcements opens new possibilities for the use of cementitious injection technology.

The pre-injection method

The basic idea of pre-injection is to treat the ground prior to the excavation by injecting a grout into the ground through drillholes

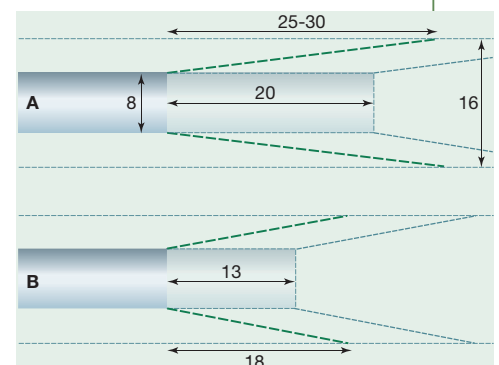
Above: Figure 1 – Drilling ahead of the tunnel face for pre-injections using a conventional drilling jumbo for hardrock drill & blast excavation;

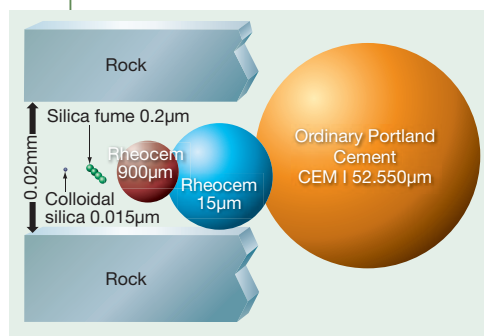
Right: Figure 2 – Schematic layout of pre-injection in hard rock tunnelling. A: percussive probe drilling pattern. B: Injection drillhole fan. Figures are typical and given in m.

and pumping at pressure.

Pre-injection basically consists of:

- Drilling of holes for the injection
- Injection until the termination criteria are reached
- Evaluation or control of the injection result: decision regarding repeated injections or to commence excavation through the treated ground





Above: Figure 3 – Graphical representation to scale of grain sizes of cement grouts and colloidal silica with respect to a relevant joint aperture in rock for penetration (0.02mm).

In addition to these three main steps in the actual injection cycle, there is an up front process of determining the main scope and location of the injection works. This includes the following important issues:

- Exploratory drillings to determine the initial state of the ground to be treated
- Exact location to establish the drillings for the injection
- Injection method, main features
- Grout types, grout mix designs

It is important to understand a pre-injection scheme in tunnelling as a sequence of decisions made at several stages in the injection cycle. Management of the injection works is therefore a crucial factor in order to achieve cost-effectiveness.

Pre-injections can have two main goals:

- To reduce the permeability of the ground and hence, reduce the flow of water into the tunnel after excavation
- To improve the mechanical properties of the ground and hence, provide improved stability of the ground during the excavation and tunnel support

Before the technical details of a pre-injection scheme are designed, one should make overall considerations regarding the method. The layout of the method comprises decisions at a strategic level for the pre-injection works, including the fundamental approach as to how to achieve the desired result. The basic framework of the operations in the injection cycle is laid out in this process.

This planning process needs to give the necessary input for the specification of equipment, such as drilling to desired length and cycle of probe drilling and injection fan drilling (figures 1 and 2). The main issues to consider in this planning process are the following:

- Ground properties and their capacity to be drilled
- Drilling method
- Packer system to suit the chosen hole diameter or pipe
- Grout mix designs to suit the required penetration, early strength and long term material properties
- Considerations regarding injection pressures
- Termination criteria for the injection process
- Simple control measures to verify that the injection result meets the requirements

It is important to understand an injection operation as a complete method. All the above mentioned issues should always be considered during the planning process.

A frequently misunderstood feature is the grouting pressure. Very often, maximum permitted grouting pressures are specified at far too low a level. The main reason for this is frequently said to be that a higher grouting pressure might feed a global pressure build-up in the ground, leading to a risk of hydrofracturing or undesired penetration of grout far away from the location of the injection.

Barton et al (2003) demonstrates that injection pressures measured at the injection lance (the collar of the drillhole) in most cases do not correspond to the pressure of the grout in the actual ground. As long as there is a flow of grout, there is a significant drop of pressure in the immediate vicinity of the drillhole into the ground. Another important issue is to always have in mind that an injection operation is a cycle in which decisions are made with regards to specific criteria. These decisions are made at each step of the injection cycle. Therefore pre-injection is a type of work that requires continuous and experienced hands-on management during the works.

Characteristics of grout

Injection in difficult ground requires the complete method to be adapted in order to achieve desired penetration. An essential detail in this context is the choice and design of the proper grout characteristics with special emphasis on penetrability.

The penetrability of a grout is difficult to measure or verify directly. Penetrability describes the ability of a grout to enter into a medium like a granular soil or fine joints in a rock mass under a certain injection pressure.

The penetrability of a grout for injection purposes in underground construction is mainly influenced by three measurable material properties: grain size, viscosity and stability. The grain size is decisive for the penetrability into fine joints, as well as

permeating between the grains in a soil. Figure 3 illustrates graphically the importance of grain size for the penetrability in joints in rock.

The viscosity is important since it will directly influence the shear stresses in a grout when it is flowing through joints or between the grains in a soil. The lower the viscosity, the lower the shear stresses in the grout and hence, the lower the injection pressure which is required to sustain the flow of the grout into the ground.

The stability of the grout is important since it will directly influence the capability of the cement in the grout to penetrate into the fine discontinuities.

The process of bleeding, in which the cement grains separate from the grout mix and clog the entrances to the fine joints, does not occur with a stable grout mix. For soil injection purposes one must consider closely which intended improvement effect and penetration mechanism that is planned when designing the grout mixes and the method. Four examples of soil improvement mechanisms are shown in figure 4.

These cements were originally designed as tunnel injection cements with the main emphasis being on cost-effectiveness in tunnelling. They are available in the grain size range typical for microcements down to the ultrafine microcement range. These cements offer particular advantages in a tunnelling situation.

Table 1

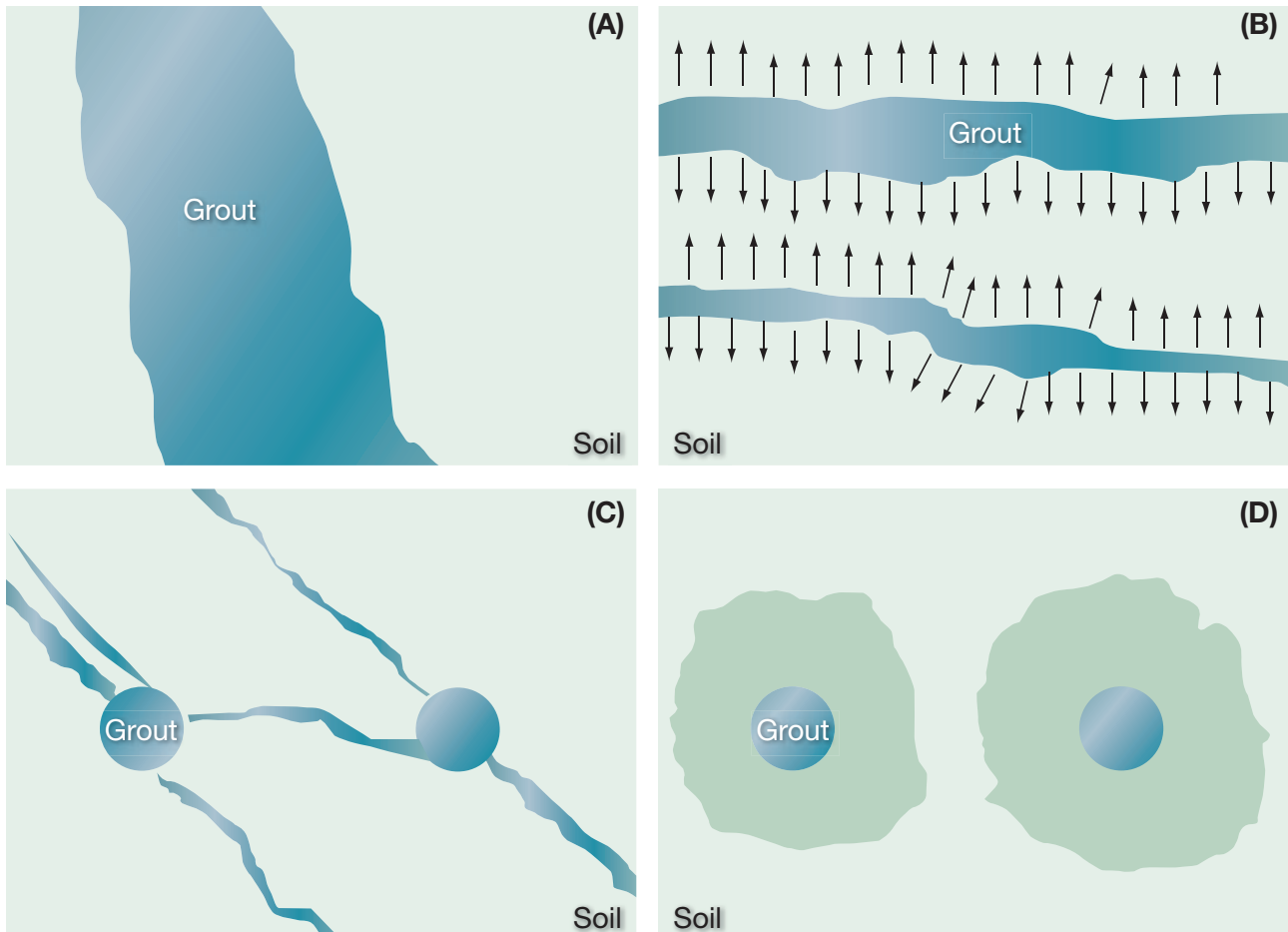
Main technical properties of liquid colloidal silica* for injection in rock and soil.

Property	Range or value
Typical grain size	0.016 µm
Viscosity of grout	5-6 mPa·s
Setting time (controllable)	10 min to 2 hrs
Final strength, pure resin	Ca 0.2 MPa
Final strength, resin & sand**	Ca 1 MPa
Final strength, resin & sand***	0.4 – 0.7 MPa

* Figures refer to MEYCO MP320

** Sand with gradation 0.2 - 0.5 mm injected in laboratory

*** Example from an in-situ injected loose sand in a tunnel



Above: Figure 4 – Simplified graphical representation of four main types of penetration of a grout in a soil. Pure grout is shown as blue. A: replacement (jet-grouting), B: compaction, C: hydrofracturing or “clackage”, shown between or out from holes or pipes, D: permeation, shown out from holes or pipes. (Holter et al 1996)

The main advantages are:

- Small grain size
- Excellent stability and low viscosity even at relatively low water/cement ratios (e.g. 1.0)
- Excellent penetrability due to the grain size distribution, stability and viscosity characteristics
- Setting within 1.5 to 2 hours (w/c ratio 1:1, 20 degrees C), eliminating practically all waiting time for setting
- Rapid setting characteristics also in cold groundwater conditions

Liquid colloidal silica grout type consists of silica grains (SiO_2) in the nanometric scale in a colloidal solution in water. The typical grain size is $0.016 \mu\text{m}$. Its viscosity is 5-6 m-Pa-s, which is slightly higher than water. These technical properties offer a unique technical performance in a number of injection situations. Colloidal silica, contrary to silicates and acrylates, is a completely non-toxic product, which makes it unique in

terms of environmental friendliness and health and safety. Colloidal silica is a mineral grout designed for permanent long-term purposes, whereas silicates only can have a temporary function.

The penetrability of colloidal silica in jointed rock and soils is illustrated in figure 4. The simplicity during application, using the same equipment as for cementitious grouting makes this system very suitable as a supplement to cementitious grouting.

Maneri Bhali hydropower project

The headrace tunnel for the Maneri Bhali hydroelectric power project phase 2 (Uttaranchal Province, India) underpasses a valley with low rock cover. The tunnel was excavated by drill and blast and supported by steel sets and lagging with concrete backfill.

The situation with valley underpass and main geological formations is shown in figure 5.

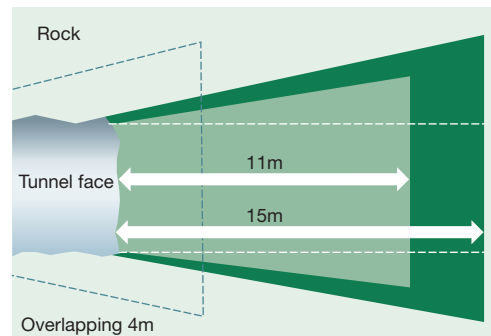
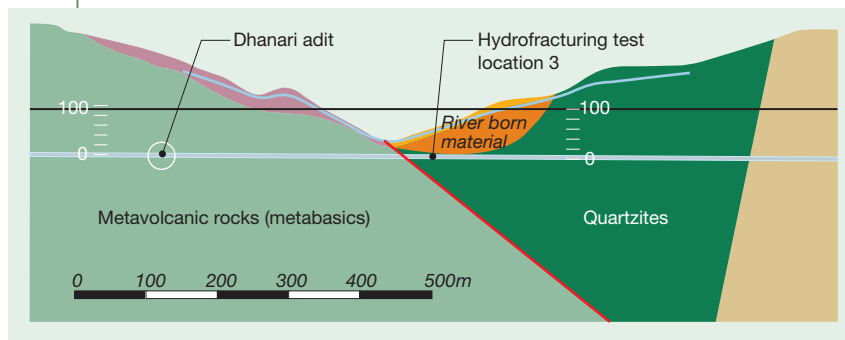
The valley corresponds to a regional

weakness zone which intersected approximately a 300m length of the tunnel. The weakness zone exhibited densely jointed and partially crushed mica-quartzite schist. In-situ fine grained crushed material in the silt fraction occurred as joint fillings. The entire weakness zone was highly permeable; hence high water inflows were encountered.

The valley had been underpassed with serious difficulty during a construction attempt several years earlier. No pre-injections were carried out at this stage. The highly jointed and crushed rock combined with the low overburden of only 20-25m (of which only ca 5m rock) at the shallowest imposed a critical point in the headrace tunnel.

The maximum water pressure in the tunnel during the operation of the power plant would be 10 bars. This would create a potential risk of hydrofracturing and leakages out of the headrace tunnel. There would also be a risk of charging of water in the surrounding ground resulting in a danger of landslides.

Previously, pre-injections with locally manufactured ordinary Portland cement had been attempted, but with very limited penetration into the ground. In order to address the difficult ground conditions, a two-stage pre-injection scheme with two



Above, left: Figure 5 – Headrace tunnel of the Maneri Bhali hydropower project. Longitudinal section of the difficult zone. (Bahadur et al 2007).

Above, right: Figure 6 – Layout of the injection method (longitudinal vertical section). The outer dark area in front of the tunnel face represents the volume which was treated in injection stage 1 with rapid setting microcements. The lighter area in front of the tunnel face represents the volume which was treated subsequently in injection stage 2, employing liquid colloidal silica. (Bahadur et al 2007).

different grout types was undertaken. The main goals of this pre-injection scheme were:

- Water ingress reduction and stabilisation of the ground in the weak zone to facilitate the establishment of a sufficient rock support as well as the structural and waterproofing lining of the tunnel
- Facilitate safe conditions for excavation and immediate support of the tunnel as well as constructability for the final lining

The main feature of the injection method was to inject through grouted steel pipes with a length of 2.5m. The high degree of jointing and crushing of the rock mass severely limited the drilling operation. Each of the steel pipes were therefore used for repeated drilling and injection.

The first drilling and injection step through the steel pipes reached 6m in front of the tunnel face.

The second step reached 8-11m, and the third and final step reached 13m in front of the tunnel face.

The first stage consisted of injection of rapid setting microfine cement. This allowed for a continuous operation with drilling, injections and the subsequent re-drilling to greater depth through the same steel pipes without damaging the result of the previously injected volume.

The second main stage was the injection of liquid colloidal silica. Featuring extremely low viscosity and grain size in the nanometric scale, the finest joints as well as joints with fillings were grouted. A very satisfactory result in terms of water ingress reduction and ground improvement was achieved.

The second stage was geometrically laid out in a way that it would be enveloped by the grouted rock mass from the first stage, as shown in figure 6.

In this way the injection of the low viscosity grout would occur where the microfine cement was already injected.

The first stage injections with rapid hardening microcement showed a relatively limited grout take of only 100-150 kg per m drillhole when the termination pressure of 60 bars was reached.

Bearing in mind the seepage, which was encountered in the drillholes, one would expect a higher grout take. The reason for the relatively low grout take was joint fillings which consisted of the silt and clay particles, which in turn limited the penetration of the grout created by filtration.

The first stage injection fan with microcement was always completed in the full circumference of the tunnel before the This was due to the first stage injection providing penetration of grout into the joints with the largest apertures.

The second injection stage with the low viscosity grout could therefore be targeted for the finer joints and the joints which were partially filled with clay and silt. The secondary fan was injected with a termination pressure of 25 bars, or approximately 100kg grout per m drillhole. Injection beyond a pressure of 25 bars with liquid colloidal silica usually showed signs of hydrofracturing.

The result was a literally dry and stable tunnel contour. No excessive breakouts of rock or cave-ins occurred during excavation through the weakness zone.

The proactive approach demonstrated in this case, that pre-injection of the difficult ground resulted in safe, cost-effective and predictable construction conditions. The effects of the pre-injection works could be directly compared to the poor conditions and heavy water flows observed in the

adjacent tunnel where pre-injections were not used.

A direct comparison of the effectiveness of microfine cements and liquid colloidal silica grout versus ordinary Portland cement was also clearly evident.

The experiences from Maneri Bhali show that a proactive approach to drilling and grouting with a clearly defined method statement and utilizing materials with the proper penetration, viscosity and rapid hardening characteristics can significantly reduce the construction time through such highly faulted, water bearing and unstable zones (6 months in by-pass tunnel versus 18 months in original tunnel). ■

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From Tokyo dream to Turkish delight



For Masahiro Iwano of Japanese contractor Taisei Corporation, geotechnical engineering has always been the path on which life would take him. Take his last name, Iwano. “Iwa” means rock masses and in Chinese characters “no” means field, he explains. “I was very interested in natural science in my childhood and simply chose geotechnical engineering as my calling.”

Currently Masahiro lives and works in Istanbul, Turkey, working as a project manager for the Marmaray Project, which includes construction of an immersed tube under the Bosphorus Strait, four stations and a total of 13km of tunnels. Of the project, working on a tunnel that the country had dreamed of for 150 years is quite interesting, he says, especially at they get closer and closer to realizing it.

Originally from Fukuoka, Kyushu Island, Japan, he went on to Tokyo University, to study natural and social science for two years. Afterwards, he studied civil engineering and, mainly, geotechnical engineering for another two years.

After graduation, Masahiro stayed in Tokyo and started working with Taisei as a design engineer in civil engineering. It was at this point that he learned tunnel design and the structural support systems of tunnels, particularly tunnels built by New Austrian Tunnelling Method (NATM) or the Sequential Excavation Method (SEM).

“I also extensively used numerical analysis such as the Finite Element Method (FEM) to simulate the mechanical deformation of tunnels due to excavation and to evaluate tunnel stability,” he explains.

In 1988 he left Japan for the US where he attended the Massachusetts Institute of Technology (MIT) and lived in Boston. A student of the graduate school, he completed Course1, which focuses on civil and environmental engineering.

“During my stay at MIT, geotechnical engineering, especially the rock mechanics and underground constructions, was a major field of study for me,” Masahiro says. For his Ph.D, he focused on hydro-mechanical characterization of jointed rock masses. And after he completed his Ph.D in 1995, he was

promoted to manager of Tunneling & Underground Construction at Taisei.

For the last 15 years he’s been working on construction projects ranging from nuclear power plants, to an underground hydraulic power cavern and road tunnels. “Tunnelling works are very exciting, dynamic and fascinating,” he says, “particularly blasting.”

He also enjoys the camaraderie the tunnelling industry offers. In Istanbul he spends his spare time travelling in Europe with friends and has visited many of Turkey’s World Heritage sites. He points out that Istanbul was chosen as one of Europe’s Capitals of Culture for 2010. With one of the station’s worksites in the heart of the city’s historical district, he’s only a few steps away from a lush green park and vibrant street cafes.

For the last Byram (a Turkish national holiday week in September) he travelled to Estonia and to Finland to visit Sandvik’s mining and construction factory to check out new tunnelling machines and drilling control systems. But it’s not all work—after visiting the factory he had the chance to race rally cars at a circuit course. “I need more practice on driving techniques to win,” he says and is looking forward to WTC 2011 in Helsinki when a rematch can be arranged.

Back in Istanbul, though, he stays off the roads. Traffic is heavy and crossing the Bosphorus from his office on the eastern side of the city to worksites on the western side is a timely process with limited routes. He makes the best of the situation by often letting someone else take the wheel while he works from within the car.

He points out that the Turkish government is starting to survey a different area of the Bosphorus Strait for another potential tunnel. When he is finished working on the Marmaray Project in a few years, he would like to work here again. “Istanbul is a fascinating city, like my home city, Tokyo. But the difference from Tokyo is a very exotic atmosphere,” he says. “I like very much living in Istanbul, and my Turkish friends and colleagues.” ■

dates & events

6 - 8 OCTOBER 2010

5th International Seminar on Deep and High Stress Mining, Santiago, Chile

Contact person:
Professor Michel Van Sint Jan
Email: deepmining2010@ing.puc.cl
Further information on the website of the seminar:
<http://web.ing.puc.cl/~deepmining2010/>

23 - 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 / cbip@cbip.org; web: www.arms2010.org

25 - 27 OCTOBER 2010

Sustainable transport and the quality of life in the city, Buenos Aires, Argentina

The main topic of the XIVth CODATU's conference is: « Sustainable transport and the quality of life in the cities ». We are required by the world's economic situation to analyze public transportation, considering issues of environmental and economic sustainability, as well as the dramatic augmentation of energy consumption, and increasingly limited resources. Contact: Codatu; tel: +33 (0)4 78 62 23 09; fax: +33 (0)4 78 62 32 99; email: codatu@wanadoo.fr

28 - 29 OCTOBER 2010

TBM Conference 2010, London, England

This year, the 4th annual TBM Conference takes place in the shadow of the prestigious Crossrail project in London. In addition to London's long tunnelling history, its geology and the changes of geotechnical ground properties caused by tunnelling will be the key issues addressed. Contact: BASF Construction Chemicals Europe; tel: +41 58 958 22 11; fax: +41 58 958 32 46; email: meycou.ugc@basf.com

9 - 11 NOVEMBER 2010

Harkány 2010 - Tunnel Construction and Civil Engineering Conference

Design and construction experiences from the tunnels on the M6 motorway
Design and construction experiences of the National Radioactive Waste Repository at Bataapáti Foresight, the near and the distant future, the vision for tunnel construction and civil engineering. Contact: Dr Tibor Horváth; tel: +36 26 319 368; email: geovil@geovil.hu

17 - 19 NOVEMBER 2010

6th conference of international Society on Underground Freight Transport (ISUFT2010)

The objective of ISUFT2010 is to provide a forum for discussion of the state-of-the-art, opportunities and challenges in underground freight transport. Contact: Prof. Chen Zhilong; email: isuft2010@163.com

22 - 23 NOVEMBER 2010

BTS underground health and safety course

Following the success of underground health and safety course in 2009 it has been decided to repeat the two day format of last year to allow more time on specific subjects and include more

discussion and debate. Contact: The BTS Secretary; tel: +44 (0)20 7665 2229; email: bts@britishtunnelling.org.uk; web: www.britishtunnelling.org.uk

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

25 - 29 NOVEMBER 2010

7th WBI-International Shortcourse on Rock Mechanics, Stability and Design of Tunnels and Slopes, Aachen, Germany

Trade event for underground utility construction focused exclusively on installation and rehabilitation of the underground infrastructure. Tel: +1-301-694-5243; Fax: 1-301-694-5124; Web: www.uctonline.com; UCT P.O. Box 941669, Houston, TX 77094-8669

25 - 27 JANUARY 2011

Underground Construction Technology International Conference & Exhibition, Houston, Texas

Trade event for underground utility construction focused exclusively on installation and rehabilitation of the underground infrastructure. Tel: +1-301-694-5243; Fax: 1-301-694-5124; Web: www.uctonline.com; UCT P.O. Box 941669, Houston, TX 77094-8669

1 - 3 MARCH 2011

International conference and exhibition on tunnelling and trenchless technology, 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. Tel: +(603) 7968-4001 / 4002; Fax: +(603) 7957-7678; Email: Tunnel2011@iem.org.my Website: www.iem.org.my

26 - 27 OCTOBER 2011

Underground Infrastructure of Urban Areas, Wroclaw, Poland

This conference will discuss topics related to building tunnels and underground infrastructure in cities, such as geotechnical tests and town planning issues. Tel: +48 71 320 29 14, Web: www.uiua2011.pwr.wroc.pl

BRITISH TUNNELLING SOCIETY

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

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 Arthur 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.

20 JANUARY 2011: East Side Access Project, New York

The \$7.3bn East Side Access Project currently under construction in the heart of Manhattan is the largest federally funded infrastructure project in the USA and forms a key element of the MTA's \$35bn capital program.

When complete the project will provide the first system expansion of Long Island Rail Road in over 100 years and provide a new rail terminus directly beneath the existing historic Grand Central Terminal in Manhattan.

This talk will discuss the program management issues, the challenges of working beneath some of the world's most expensive real estate and the interface and coordination issues that arise when 95 per cent of construction is within operational railroad right of way.

This talk will also present an overview of the multitude of tunnelling methods being used, including the first use of slurry TBMs in New York to excavate the 50,000 linear feet of tunnel and 800,000 cu.yd of associated cavern and access tunnels whilst remaining mostly invisible to the public.

This presentation is given by Alan Paskoff of MTA Capital Construction and Andy Thompson - Hatch Mott MacDonald

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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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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