

FEBRUARY 2011

tunnels & tunnelling

INTERNATIONAL



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Special report: Mediterranean

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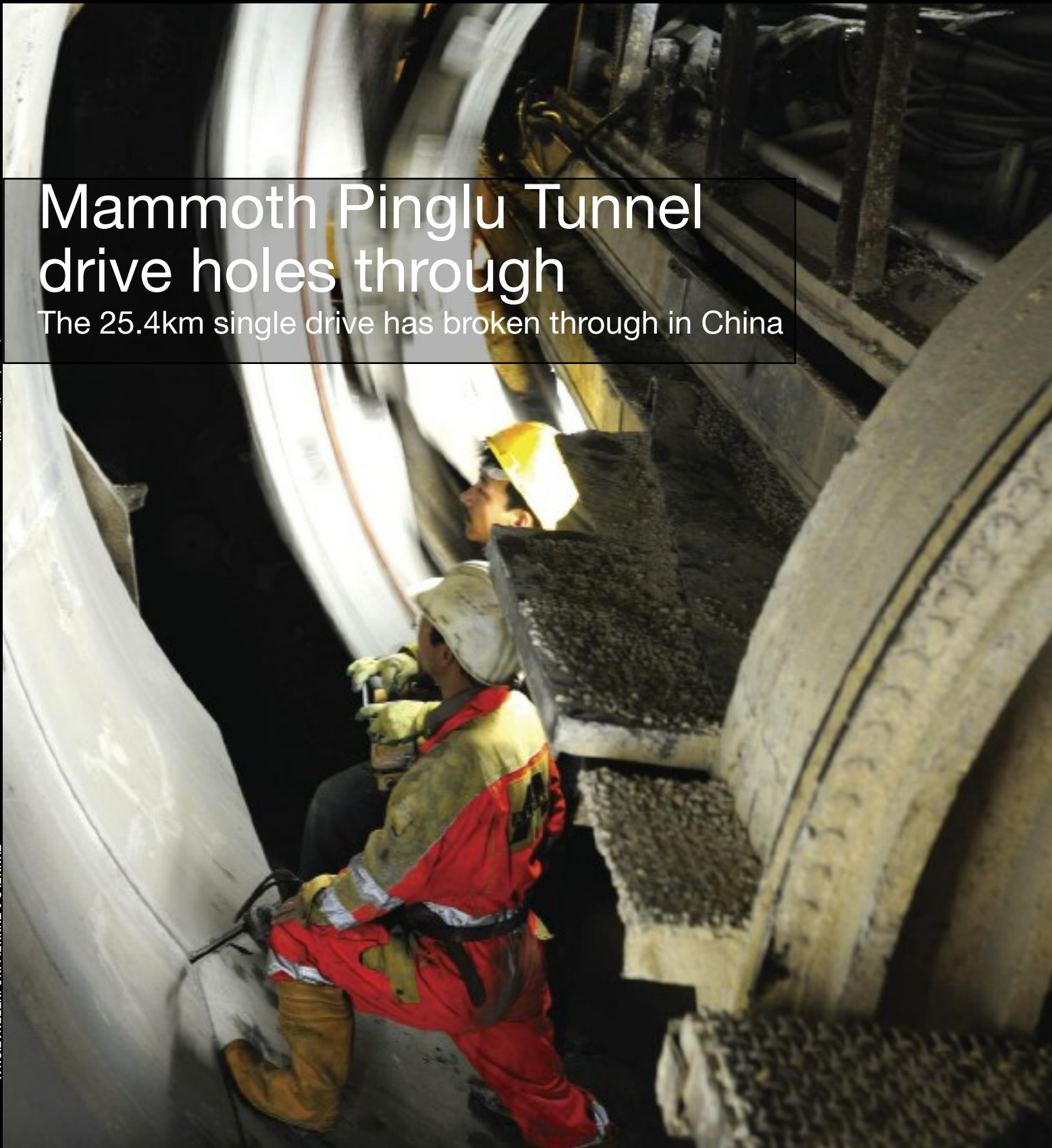
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Mammoth Pinglu Tunnel drive holes through

The 25.4km single drive has broken through in China



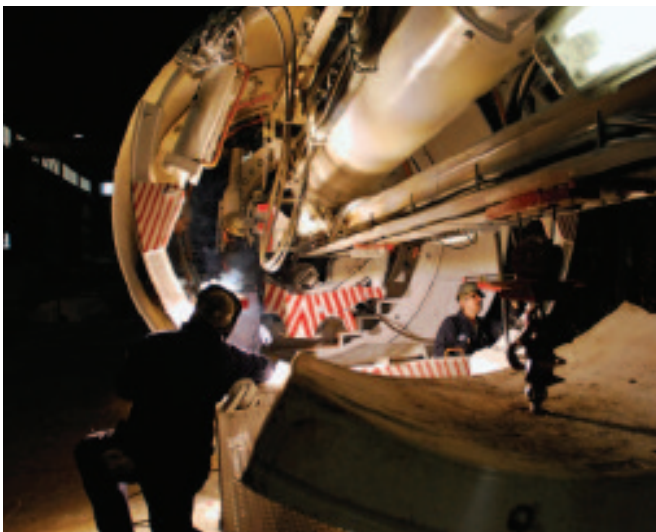
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comment

Spanish armada sinks competition

Spanish contractors have made a massive impact on the tunnelling industry in recent months winning successive major tunnelling contracts and leaving their competitors wondering how on earth they are going to compete. Last month's award of Seattle's Alaskan Way Viaduct Replacement Tunnel design and build contract to Spanish contractor Dragados (see page 5) was the latest in a series of big wins for the company and for other Spanish contractors.

Spanish firms are winning on price. They more than meet the standards of any international contractor but are able to offer an unbeatable price. In more typical circumstances, a very low tender would indicate a company desperate for work. But this is not the case, even though the workload in Spain has dropped dramatically. The firms are winning jobs left, right and centre.

Late last year Spanish construction giant Ferrovial bagged the western running tunnels contract on Crossrail and Dragados won the eastern running tunnels.

One contractor, perhaps slightly bitter at losing the largest Crossrail contracts, told *T&T* that the Spanish firms had left themselves with few opportunities to make money on the project and many opportunities to lose it.

A forerunner to the big push by Spanish firms to win work abroad was the East Side Access project in New York. In 2006 Dragados won the USD 430M construction contract, bringing with them their own TBMs.

Perhaps the secret lies in the structure of these companies. To enable high risk ventures in bidding low for work the companies need security. The lending banks want to see that the contractor is going to stay afloat if the gamble doesn't pay off so they can get their money back. So where is the collateral?

Dragados is part of Grupo ACS. The group is made up of construction outfits, a long list of industrial services companies, such as port operators and maintenance firms, and has investments in other firms, such as German construction giant Hochtief. The diversity of the group helps spread its risk and offers collateral to secure it better lending terms from the banks.

Likewise, Ferrovial has its fingers in many pies other than construction. The firm secured a massive asset in its takeover of UK airport operator BAA in 2006. It has diversified into waste management, maintenance and airport services, such as ground handling.

Favourable lending terms and a diversified portfolio may be some of the tricks Spanish contractors are relying on to beat the competition. But, however it is being managed, the Spanish contracting empire is dominating the new major tunnelling projects in the West. To compete, rival firms may have to rethink their strategies and find ways to lower their costs.

Jon Young

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Breaking through on China's Pinglu Tunnel, a 25.4km single drive



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BREAKTHROUGH IN HAMBURG: VERA IS ONE MONTH AHEAD OF SCHEDULE.

Hamburg is building metro line U4 to provide a direct and quick link between the new HafenCity and the city center. The journey from "Jungfernstieg" station at the inner Alster to "HafenCity Universität" station at the Elbe River will only take 4 minutes. The citizens of the Hanseatic city nicknamed the Herrenknecht S-440 tunnel boring machine (Mixshield Ø 6,570mm), which is excavating the two parallel tunnels, V.E.R.A. (German abbreviations for "from the Elbe River towards the Alster River").

The tunnelling specialists of the U4 HafenCity Consortium were able to celebrate the final breakthrough on December 3, 2010, one month ahead of schedule, after having mastered sometimes demanding geological conditions with bravura. This means that the final development phase of the tunnel tubes is advancing as scheduled and that the metro can presumably be put into operation as planned in fall 2012. After final completion of the HafenCity project, the Hamburger Hochbahn AG expects that 35,000 passengers per day will use the U4 metro line.

HAMBURG | GERMANY

PROJECT DATA	CONTRACTOR
 S-440, Mixshield Diameter: 6,570mm Cutterhead power: 450kW Tunnel length: 5,620m (2x 2,810m) Geology: gravel, clay, sand, silt	ARGE U4 HafenCity (HOCHTIEF Construction AG, E. Züblin AG, AUG. PRIEN BAUUNTER- NEHMUNG GMBH & CO. AG, HC HAGEMANN GmbH & Co. KG)




Dragados-Tutor Perini sign Alaskan Way contract

USA

The Seattle Tunnel Partners joint venture, led by Spanish-owned Dragados, has signed the USD 1.35bn contract with the Washington State Department of Transport (WSDOT) to build the Alaskan Way Viaduct replacement in Seattle.

The contract, signed on 6 January, to design and build the two-level, 2.7km-bored tunnel, marks a trend of Spanish firms successfully investing and finding work away from their recession-hit homeland.

The joint venture of Dragados USA and Tutor Perini, with Frank Coluccio Construction, Mowat Construction and HNTB Corp, was one of two teams that competed for the design-build contract, which

included tunnel boring, mitigation for tunnel settlement, construction of tunnel portals, building the road within the tunnel and constructing two operations buildings.

In addition to Seattle Tunnel Partners' proposal price of just under USD 1.09bn, the contract includes allowances for inflation, bonding and insurance requirements. Utility work reimbursed by the city is also included in the contract, bringing the total contract amount to USD 1.35bn, with up to USD 70M in incentives.

"With this contract, we are confident that the tunnel will be built within budget and delivered on time," Washington transportation secretary Paula Hammond said. "More than 90 per

cent of the design-build work will be performed for a fixed price."

WSDOT said Seattle Tunnel Partners will continue preliminary design work in February.

If tunnel plans are approved following the project's environmental review, expected this summer, the agency will direct the design-build team to begin final design and construction of the bored tunnel.

Total cost of the proposed bored tunnel is estimated to be USD 1.96bn. This includes design, right-of-way acquisition, construction management, and more than USD 200M set aside for risk. The total estimate includes separate, future construction contracts for roadway connections at the north and south ends of the tunnel.

News in brief

Spanish firms secure Spadina contract

A CAD 404.4M (USD 407M) contract to build the 4.5km north tunnels and Highway 407 Station of the Toronto-York Spadina Subway Extension has been awarded to a joint venture of FCC Construction and Obrascon Huarte Lain. The project will be built by two TBMs in three phases. The station will be 165m long, 22m wide and 23m deep.

Christie and NJ won't pay

The state of New Jersey has filed an appeal over USD 271M of federal money that it owes for the ARC tunnel cancelled in October by governor Chris Christie. Legal representatives filed the appeal on behalf of the state on 25 January, the deadline for the money to be returned to the Federal Transit Administration.

Devil's Slide tunnel nearing completion

Contractor Kiewit finished excavating the 1.3km tunnels for the Devil's Slide road project beneath the San Pedro Mountain in California. Drill-and-blast and roadheader excavation were used for the twin-bore tunnel, each 9m wide.

Salini to build the Copenhagen metro

DENMARK

Salini signed a EUR 1.7bn (USD 2.21bn) contract on 7 January making it the leader of the Copenhagen Metro Team.

Comprised of two other Italian companies, Tecnimont and Sell, this team will commence works later this month for a scheduled completion date in 2018.

The metro development, known as the Cityringen project, consists of a new circular line in the city centre featuring two 17.4km tunnels and 17 new stations, all at 30m below the surface. This presents a particular technical challenge, as the city is at sea level.

When completed, the metro will run continually for 24 hours per day. The driverless, automatic train

system will transport an estimated 130 million passengers annually.

On winning the contract, Salini said, "The client, Metroselskabet, has recognised Salini's commitment to using a local workforce and local companies wherever possible, upholding the highest standards of health and safety, and minimising the impact on the daily lives of the city's inhabitants."

Laotian TBM era dawns as first ever drive completed

LAOS

The first tunnel ever driven by TBM in Laos has been completed. Italy-based contractor CMC di Ravenna excavated the 5.5km headrace tunnel on the Then Hinboun Expansion project.

A 7.6m single shield TBM was equipped with an articulated cutterhead fitted with overcutters to enable the machine to excavate

up to 100mm beyond the normal tunnel diameter. This was to combat possible squeezing caused by the soft rock present. The 17-inch disc cutters were back loading.

A probe drill was used to check ground conditions up to 60m ahead of the machine. Some 95 per cent of the rock encountered along the drive was rated at good to fair with small sections of poorer rock quality.

"We encountered an anticipated 15m wide fault zone at about the 4,700m mark with flowing water," said Luca Barbara, far east manager for CMC di Ravenna. "We were able to drill a borehole and use expanding foam to consolidate the ground, allowing us to resolve the problem and continue boring in about one week."

To support the ground and provide final lining, 280mm thick,

pre-cast concrete segments are being used in a 5+1 arrangement, making a finished tunnel diameter of 6.9m.

The contractor last month began dismantling and moving the TBM to other projects in the region. The last 100m of the works will be completed by drill and blast once flooding in the tunnel, caused by the rainy season, recedes below the tunnel invert.

Queensland floods holding Leighton



Above: Flood waters have caused chaos in Queensland

AUSTRALIA

Ongoing flooding in Brisbane embroiled the region in chaos and the underground construction industries have not been exempt from this.

Leighton Holdings announced that it has implemented temporary project shutdowns and will leave provisions for employees, the latter being primarily for family and community assurance—no injuries to personnel were reported.

Mining operations were affected by flooding from late December although some operations recommenced, others were still

engaged in dewatering procedures as *T&T* went to press.

Speaking on 12 January, CEO of Leighton Holdings, David Stewart, said that operations have been totally halted at the company's largest infrastructure project, the AUD 4.1bn (USD 4.08bn) Brisbane Airport Link.

"Staff are currently undertaking activities to protect project works and plant and equipment, however we expect that a number of offices and some sections of the project will suffer inundation over the next 24 hours," he said.

Project teams have been working to remove significant equipment, only as a precautionary measure.

Glendoe fatality fine

GREAT BRITAIN

Hochtief Construction has been fined GBP 266,000 (USD 412,000) at the Inverness Sheriff Court for a breach of health and safety legislation. The case was brought following the death of site worker and 'telehandler' operator Ondrej Hladik on 22 September 2008. Hochtief was part of the joint venture constructing Scottish and Southern Energy's (SSE) Glendoe hydropower project near Fort Augustus, Scotland.

As Hochtief pleaded guilty, the fine was reduced from GBP 400,000 (USD 634,000). Although Hladik, from Prague, was not directly employed, as main contractor Hochtief was still deemed responsible for not ensuring the health, safety and welfare of all site workers.

A statement from the Crown Office and Procurator Fiscal Health & Safety Division said that the 'telehandler' (rough-terrain forklift truck) driven by Hladik was in extremely poor condition including the absence of a large window that would, if in place, prevented any

part of Hladik's body from being exposed to risk of being struck by the equipment's boom as it lowered. It's believed that Hladik was leaning through the aperture of the missing window at the time.

There has been a series of safety related incidents on the 100-MW Glendoe project, Scotland's biggest hydropower scheme for more than 50 years. The Health & Safety Executive lists five Prohibition Notices served on the JV relating to 12 breaches of health and safety legislation.

After the project became operational and opened by the Queen in Summer 2009, a rock collapse occurred in water-carrying headrace tunnel in August, from which the scheme has not yet been recovered. The latest forecasted (September 2010 in SSE's five-year programme) date to return to operational power generation was 2012 compared to the previous date of April 2011.

SSE confirmed in November 2010 it begun consultations about a larger hydropower scheme above Loch Ness, capable of producing six times more power than Glendoe.

Second breakthrough at A Luoi hydropower project

VIETNAM

A second branch tunnel was broken through on 27 December at the A Luoi hydropower project, located on the A Sap River in Thua Thien Hue Province, Vietnam, following 1.8 miles (2.9km) of excavation between the two sub-tunnels.

Cavico was awarded the contract for the excavation of the tunnel as well as four branch tunnels, a surge tank, a vertical shaft and an access road by Central Hydropower Joint Stock in 2007. The project was projected to provide Cavico with USD 53M in revenue. The 7-mile (11.3km) long, 16-foot (4.9m) headrace tunnel is the longest, and considered to be the most

sophisticated tunnel in Vietnam.

Upon completion the 170MW power plant will generate 686MkWh of power annually for the region.

"We are pleased to achieve another breakthrough on the A Luoi Hydropower project," said Hai Thanh ran, vice president of Cavico. "Our efficient, highly skilled team continues to deliver top-quality work on this complex project. We remain focused on completing this project in the safest and most timely manner to generate the highest possible gross profit for our shareholders."

The first sub-tunnel breakthrough was achieved in August 2010.

News in brief

Construction to start on Norwegian road tunnel
Veidekke Entreprenor has won a NOK 268M (USD 46M) to build a 3.5km, two-lane tunnel for classified road 13 in

Rogaland county, Norway, it announced on 24 January. The tunnel from Vatne to Skreppeneset would replace the current classified road 13 through a landslide-prone area. Work will begin in February and is scheduled to complete by November 2013.

Pinglu Tunnel drive breakthrough

CHINA

Breakthrough on the Pinglu Tunnel in China has been achieved, Robbins announced on 27 December.

The contractor, a Sino-Austria Hydraulic Engineering Company JV led by Alpine Bau holed through on the 25.4km, single-drive TBM tunnel on 14 November 2010.

A 4.8m diameter Robbins double shield TBM was used for the bore that forms part of China's Yellow River Water Diversion Project. The advance rate reached around 70m per day, encountering difficult geology including coal seams and abrasive sandstone with up to 70 per cent quartzite content.

Described by Robbins as a 'veteran' machine, it was also in use a decade ago for a 12km section of the same project. During this run, it set two world records for its size class: best month for a 1,855m drive and highest monthly

average at 1,352m. The records have yet to be beaten.

Despite being originally designed for similar geological conditions, some changes were needed for the TBM to operate efficiently on this drive. "The back-up frame was extended from one stroke to two strokes. This was a key change, especially for such a long tunnel," said Meik Mueller, technical director for Alpine's Asia division. "The modification allowed the machine to maintain good advance rates despite transit times of up to 70 minutes for muck trains travelling from the machine to tunnel entrance."

Lining for the Pinglu Tunnel, consisted of unique hexagonal segments and was produced near the jobsite by Alpine. A crew of nearly 400 people worked at the remote site and segment factory to cast the specialised structures. During tunnelling the segments were placed in rings of four elements in a



Above: China's Pinglu Tunnel saw a breakthrough in late 2010

honeycomb configuration staggered longitudinally.

The Pinglu Tunnel will be up and running by October 2011 and will

connect the North Main Line of the Yellow River Project to allow water transfer to Pinglu, Shuozhou and Datong.

Third bypass contract for Chun Wo

CHINA

The Chun Wo-led joint venture of Chun Wo, China Railway Group and China Major Bridge Engineering Company has been awarded a third contract for the Central Wan Chai Bypass to be constructed in Hong Kong, China.

The contract was valued at around HKD 4bn (USD 514.43M) and was awarded by the Highways Department of the

Hong Kong Special Administrative Region.

Under the terms agreed, Chun Wo will construct a 300m tunnel at East Portal in the North Point area of the Eastern District of Hong Kong as well as roadworks, demolition and other associated works. The tunnel forms part of the 4km bypass. When completed, it will serve about 60 per cent of the current East Island Corridor traffic.

Total cost of the overall project was projected at HKD 20.5bn (USD 2.64bn) in 2008.

Chun Wo deputy chairman Derrick Pang said, "We are delighted that Chun Wo has successfully secured a handful of new projects at the start of the year, especially another project for the Central-Wan Chai Bypass.

"The awarding of these contracts to Chun Wo fully represents recognition of our strong abilities in delivering quality construction works."

He added, "With the support of the Hong Kong government upgrading of the Special Administrative Region's infrastructure and for the construction industry, Chun Wo is well-equipped to benefit from the resulting growing demand from the booming industry."

Left: The alignment for the Central Wan Chai Bypass



Himalayan road tunnels

INDIA

Bernard Ingenieure has earned a consultancy role for the design and project reports of three road tunnels in Himachal Pradesh, India.

The firm triumphed over competition from a Geoconsult Seon and Euro Studio JV as well as AECOM with the lowest bid of INR 6.25 crore (USD 1.39M). In doing so, it has entered into the public-private partnership (PPP) with the Infrastructure Development Board.

The longest of the tunnels at 5km will be bored from the Kangra valley to the Chamba valley through the Dhauladhar mountains, the second will be built in the Mandi district and the third at 1.2km will also be built in this area.

The total cost of the tunnels is estimated at around USD 145M.

Crossrail station tunnels award

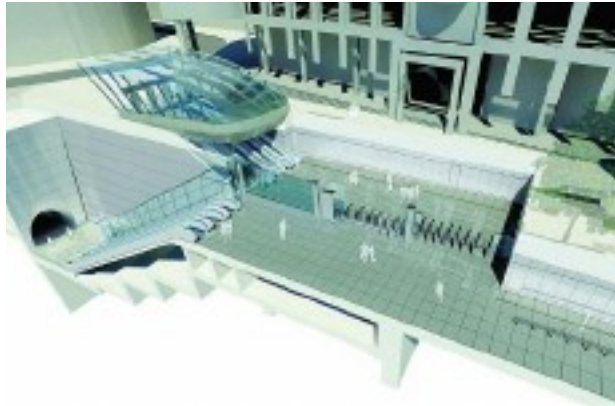
GREAT BRITAIN

Crossrail has awarded a GBP 235M (USD 373M) contract to a joint venture of Balfour Beatty, Alpine BeMo Tunnelling, Morgan Sindall and Vinci Construction for construction of the Liverpool Street and Whitechapel station tunnel contracts, according to a statement issued by Balfour Beatty.

The joint venture group appears to be unsuccessful in winning a main running tunnels contract, according to Crossrail announced intentions, but this work is also a substantial win. Balfour Beatty said it has a share of approximately 30 per cent of joint venture and that the JV will provide the full range of skills, resources and technical expertise for the complex project.

The contract covers the construction of all station tunnels and associated works in this stretch. The Crossrail station, located deep beneath existing London Underground platforms, will provide interchanges with London Underground's Central, Metropolitan, Circle and Hammersmith & City Lines as well as the Northern Line, plus connections to London Stansted Airport and national rail services.

In mid-2009 a team of consultants, with lead design by Mott MacDonald, was appointed to work on Liverpool Street station



Above: A computer generated visualisation of the redeveloped Liverpool Street Crossrail station

including enabling works to create sufficient space. Mott MacDonald has a dedicated sprayed concrete lining (SCL) design team to standardise the approach to this discipline. Crossrail says that a connection between Crossrail and London Underground's Northern Line and the neighbouring Moorgate Station involves a particularly challenging SCL stairway construction beneath an existing deep escalator adjacent to Northern Line platforms.

A 40m-deep box structure will be located on Blomfield Street to accommodate ventilation, electrical and mechanical systems equipment and there will be a new ticket hall beneath Liverpool Street close to the Broadgate development.

Crossrail announced an improved design for Whitechapel Station last June. There will be four new structures: the 200m-long Crossrail platforms in tunnel, Cambridge Heath Shaft, Durward Heath Street, plus the ticket hall and concourse.

A bank of three escalators to the new concourse will link the platform tunnels. Tunnels will be excavated from a temporary shaft at one of the Cambridge Heath Shaft worksite.

Crossrail has also submitted a planning application with detailed designs for Bond Street Station in London's West End. The new Crossrail station will be integrated with the existing London Underground station.

Cavico to extend Vietnamese hydropower

VIETNAM

Vietnam based Cavico announced on 28 December that it has entered into a USD 6M contract with the state owned Electricity of Vietnam (EVT) for construction work on the Song Bung 2 hydropower project.

Under the agreement Cavico will build three tunnels, a surge tank and a power house on the site which is on the Vu Gia-Thu Bon River, near Lae village, Vietnam.

A completion date has been set for 2014.

The total USD 183M plant proposal is one part of Vietnam's National Development Plan. The plant will have a capacity of 100 megawatts, producing 426Mkwh annually.

The contract includes contingency clauses for cost escalation as a result of unforeseen difficulties.

"Cavico is delighted to be awarded this construction contract for the Song Bung 2 Hydropower project," commented Hai Thanh Tran, vice president of Cavico.

"Our team and equipment are ready to be deployed to the site, and we anticipate a smooth transition into the construction process, which we expect to complete within the agreed time frame."

Skanska chosen to build deep cable tunnels

UK

Skanska announced on 5 January that it has been awarded a contract to build approximately 33km of cable tunnels through the centre of London.

Awarded by Costain working for electricity distribution company National Grid, the contract is worth GBP 92M (USD 143.4M).

The overall contract for the

project was awarded by National Grid to Costain in October 2010 and was valued at around GBP 200M (USD 312M).

The tunnels will be between three and 4m in diameter and will be situated 20 to 60m below ground and will serve the National Grid network, housing the new high voltage electricity cables that will run between Hackney and Willesden via Kensal Green and Kensal Green to Wimbledon.

Construction will begin this year with tunnelling concluded by the end of 2014.

Total completion of all associated works is set for November 2018.

The contracts also require the construction of ventilation equipment and all necessary access shafts to be completed as part of the package.

"Our ambitious tunnelling programme will be built below the

existing network, minimising disruption while making sure we continue to deliver a reliable service to millions of people and businesses.

"As well as replacing the existing system and increasing the capacity of the network, the new tunnels will make it easier for us inspect and maintain these circuits safely and efficiently well into the future," said Michael Dyke, UK construction Director for the National Grid.

BORING THROUGH FUTURE

INDIA
Khishanganga Project

TURKEY - SURUC
Water Tunnel Project



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Malaysian water transfer project awards contract

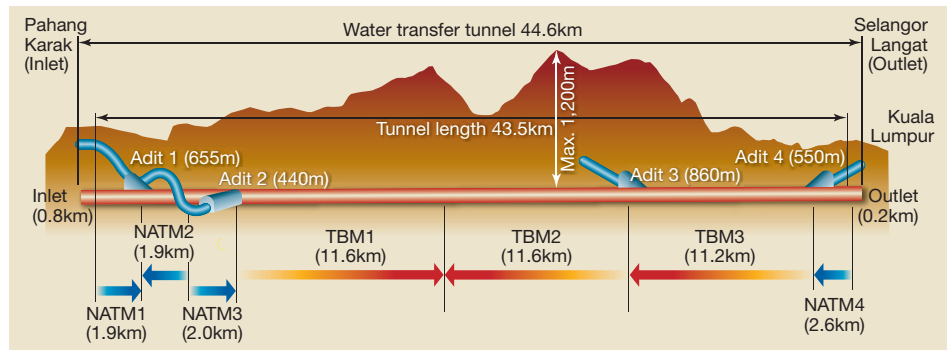
MALAYSIA

The Malaysian Government has awarded a EUR 375M (USD 483.9M) tunnelling contract as part of the Pahang-Selangor Water Transfer Scheme.

The Shimizu, Nishimatsu, IJM and UEMB joint venture presented the winning bid.

The tunnel will run for 45km at 5.2m in diameter. Three TBMs will be used for excavation of the tunnel with four drives close to the portals excavated using NATM.

Rock encountered has been mostly hard granite with overburden ranging from 20m to a maximum of 1,200m. Four adits will be sited along the route. The



Above: Three TBMs will be used to drive the Pahang-Selangor water transfer tunnel

TBMs were supplied by Robbins, specially designed to deal with the geological conditions.

The Japanese International

Cooperation Agency (JICA) and the Government of Malaysia have funded the project.

Excavation progress is currently

at around 20 per cent complete and is expected to be finished by the end of May 2014, lasting a total of 60 months.

Sydney pedestrian tunnel to go ahead once more

AUSTRALIA

New South Wales Premier Kristina Keneally confirmed that the cabinet had approved the AUD 6bn (USD 5.98bn) Barangaroo Concept Plan, which featured an AUD 286M (USD 285.23M) investment in a new pedestrian tunnel.

The proposed 9m diameter tunnel will run for 200m linking the Barangaroo suburb of Sydney with Wynyard Station and was budgeted at AUD 1.4M (USD 1.41M) per metre. Chief executive of the Barangaroo Delivery Authority, John Tabart, attributed the high cost to property purchase and demolition works.

The pedestrian link was originally part of the proposal for the metro network and included a station at Barangaroo. However, when the government cancelled the metro plans earlier in 2010, the pedestrian link was scrapped.

"The pedestrian tunnel will be

funded as part of the AUD 50.2bn (USD 50.07bn) Metropolitan Transport Plan," said minister for transport John Robertson.

The government considers Barangaroo a "once in 200-year opportunity for the city to grow." Barangaroo will be one of the first carbon neutral, water positive and zero waste business districts in the world.

"Today's announcement is a major step in our delivery of one of the biggest and most prestigious urban renewal projects in the world," Keneally said, speaking on 16 December 2010.

Cavico holes through on Vietnamese hydro project

VIETNAM

Cavico has announced the complete breakthrough of the main tunnel at the Dong Nai 4 hydropower project. The tunnel is 2.9 miles (4.7km) long and spans 30.2 feet (9.2m) in diameter.

The contract was awarded by the current Vietnamese Prime Minister, Nguyen Tan Dung in 2007. The plant, located in the Bao Lam district of Lam Dong province, has the widest tunnel in Vietnam. The contract was valued at USD 26.6M when signed in 2007. The entire project has cost the state-owned

client, Electricity of Vietnam (EVN) around USD 301M.

"We are pleased to achieve this major milestone at the Dong Nai 4 hydropower project," said Hai Thanh Tran, vice president of Cavico. "This is one of the country's most critical hydropower projects, and EVN is one of Cavico's most important strategic clients. We are proud of our recent accomplishments. Construction at the Dong Nai 4 plant continues on schedule, and we remain focused on concreting and completing the works in a timely and efficient manner."

News in brief

Death at ONKALO

A worker at the construction site for the ONKALO underground research facility in Olkiluoto, Eurajoki, Finland, died on 2 January at the back

of a tunnel reaching more than 400m depth in places. Three workers equipped with iron bars were scaling the tunnel walls and ceiling. One of the workers was caught under a block of stone being barred down and died of the

injuries he sustained. The excavation of the underground research facility in the Olkiluoto bedrock has been ongoing since 2004. Until now no severe accidents have occurred in relation to the excavation of ONKALO.



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To learn more please visit www.vinci-construction-projects.com/british-isles



GRANDS PROJETS

Rob Holden to leave Crossrail

GREAT BRITAIN

Crossrail's Chief Executive Rob Holden has quit after nearly two years working on the project.



Appointed to lead the organisation responsible for the new London and South East mega rail project in April 2009, Holden will now step down during 2011.

Holden notably led Crossrail through the Comprehensive Spending Review with no major changes in scope forced upon the project.

Some GBP 1bn (USD 1.6bn) of savings were also identified at this time.

Terry Morgan, chairman of Crossrail, said, "We regret his decision to step down but respect it. He leaves the project in great shape and we are on firm foundations to maintain our momentum to deliver this critically important project for the UK, on time and within budget."

Crossrail said Holden is leaving to explore new opportunities.

Left: Rob Holden

Morgan said, "He has successfully taken Crossrail from the drawing board, through the detailed design process [...] to the award of the main tunnel contracts late last year and the start of full construction."

Holden said, "I leave Crossrail confident that, with its funding firmly in place, a robust delivery plan, clear governance and a strong delivery team, Crossrail is now well set to move forward to a successful launch."

The exact date of Holden's departure has yet to be finalised, but Crossrail has begun the hunting for a successor.

Prior to Crossrail, Holden came from London & Continental Railways, where he oversaw the successful delivery of the new High Speed 1 railway between St Pancras International in London and the Channel Tunnel. Previously, he was also the chairman of Eurostar UK.

News in brief

Call for bids on electricity project in Malta

Enemalta Corporation is seeking tenders for excavation and construction of a service gallery located near Maghtab, Malta. The contract will run for 12 months and includes associated ventilation and access shafts, plus any other civil works which may be required. The deadline is 17 March 2011.

German rail seeks site supervision services

Deutsche Bahn is accepting bids for construction site supervision services on the Erfurt-Leipzig/Halle rail line in Germany. The contract concerns the section between Erfurt and Grobers in 11 packages, including 15km of tunnels in number 2 and 14km of tunnels in number 4. The bid closes on 21 March 2011.

Test services required for motorway project

A local authority in Germany is inviting tenders for performance test engineering services for the 1,350m twin tube Kuechen tunnel on the A44 motorway. Client is Hessisches Straßen- und Verkehrswesen (or Hessian state office for roads and transport) Bids will be accepted until 23 February 2011.

Bosnia and Herzegovina motorway project awarded

JP Autoceste FBiH, a local highway manager in Bosnia and Herzegovina, signed on 24 January a contract for preparation of main design documentation for the Tarčin - Konjic section of the 5c corridor motorway to a joint venture led by consultancy firm IPSA Institute Sarajevo, with IGH Zagreb and TZI Sarajevo. The Tarčin - Konjic corridor concerns Lot 2 (from km 11+050 to km 22+150) and includes 13 tunnels. The contract is valued at BAM 6.9M (USD 4.8M) including VAT, and construction will last 20 months.

Jacobs establishes new office on New Zealand...

NEW ZEALAND

Jacobs Associates has announced the opening of its second Australasian office, located in Auckland, New Zealand. The office was opened in October.

It is intended that the new office will support ongoing Jacobs endeavours in New Zealand, such as the Central Interceptor

Project for Watercare as well as the Waterview Connection highway tunnel project and other jobs for the New Zealand Transport Agency.

Jacobs has a long history of working on projects in New Zealand dating back to its founding in 1954 including dispute resolution on the Clyde Dam in 1986, review and cost estimation for the Waihi Gold Mine in 1993

and a feasibility study for the West Valley Sewer Project in 1995.

Isabelle Lamb, a senior associate at Jacobs who helped establish the new office said, "New Zealand is a great place for Jacobs Associates. Our company fits the local New Zealand cultural aspirations of a small but determined population of world-beaters—and I am not just talking about the All Blacks and rugby!"

...and acquires a share in Aker

NORWAY

Jacobs has acquired a portion of Aker Solutions process and construction (P and C) operations for USD 675M.

Oyvind Eriksen, executive chairman of Aker Solutions, said, "In August, Aker Solutions

announced the decision to separate the P and C business area from the Aker Solutions Group. Since then, we have explored alternative methods of separation, including an IPO and public listing. As the alternatives matured over the recent weeks, a sale to Jacobs evolved as the

preferred solution industrially as well as financially."

The executive vice president of Aker Solutions P and C, Gary Mandel will stay with the business, under new ownership at Jacobs.

The deal is expected to close in the second quarter of 2011.

Aecom appoints new European chief executive

EUROPE

Steve Morriss has been appointed chief executive of Aecom's Europe operations as of 4 January. Morriss will coordinate the company's 5000 employees working in 21 countries across the continent.

Most recently Morriss was employed at Mouchel where he was managing director of government and business services, one of the company's four divisions. In this role, he led over 4000 employees working for both government and commercial clients. This accounted for more

than a third of Mouchel's annual revenue. His 22-year career also included stints in senior executive roles for Serco and WS Atkins.

"Aecom is delighted to announce that Steve Morriss will lead our European operations," said Aecom president and CEO John Dionisio. "Over the past year, we have adjusted our business in Europe to meet the evolving market conditions and we have added significant new capabilities through acquisition."

Aecom's major interests in Europe include the Crossrail and Shard projects in London as well as others such as the La



Above: CEO Graeme Leibel said the record shows resilience

Sagrera-Nudo de la Trinidad in Barcelona and consultancy for the 2012 Olympics.

News in brief

Invitation to tender for Polish canal tunnel

Przedsiębiorstwo Komunalne (PK) has sent out an open invitation to tender for construction of a canal tunnel and all associated works are to be built in Wronki, Szamotuly County, Poland. Deadline for submissions was set as 15 February 2011.

Copenhagen metro contract award

The Copenhagen Metro Team JV of Salini Costruttori, SpA, Tecnimont and Seli has been awarded the contract for construction of the Copenhagen Cityringen metro. The EUR 1.7bn (USD 2.33bn) project calls for the construction of 17.4km of tunnels and 17 stations at a depth of 30m.

Call for bids on Iceland hydroelectricity plant

Icelandic power company Landsvirkjun has invited contractors to tender for supervision services on the new 80MW Buoarhals hydroelectricity project, located 150km east of Reykjavik, Iceland. Works include a 4km headrace tunnel to be constructed with drill and blast. Closing date 22 March 2011.

Hitachi TBM sales

Japanese firm Hitachi said it has received seven new orders for TBMs from international customers. The orders were valued at around JPY 4.5bn (USD 54M). Four of the machines were ordered to Singapore, one to Hong Kong, one to Korea and one to Taiwan.

Meyco design course

The Radisson Blu Royal Hotel, Trondheim, Norway is the venue for a tunnel design course being organised by Meyco on 15-16 March. The main goal is to address design of permanent single-shell waterproof tunnel lining.

Lend Lease purchases Valemus Australia

AUSTRALIA

Lend Lease announced on 21 December that it had reached an agreement with Bilfinger Berger to obtain a 100 per cent stake of Valemus Australia.

The acquisition was valued at AUD 960M (USD 952.8M) to be financed by existing cash reserves held by Lend Lease and an AUD 225M (USD 223.3M) five-year debt facility.

Lend Lease is the parent company of Abigroup,

Baulderstone and Conneq. Valemus is a leading provider of engineering, construction, residential and non-residential building services in Australia.

Lend Lease believed that this move would enable it to diversify its position in the sector and enable it to expand its capabilities as it came into possession of over 150 standing contracts, a secured future revenue of AUD 5bn (USD 4.96bn) per annum and Valemus's extensive government client base. It also identified beneficial senior

management experience in Valemus.

"It presents the opportunity for Lend Lease to take a leading position in the engineering and construction market at an attractive price," said Steve McCann, chief executive officer and managing director of Lend Lease.

Including risk provisions for contractual warranty obligations, Bilfinger Berger said that the capital gain from the sale is expected to be in the range of EUR 160M (USD 219.4M).

Leighton sells Indian stake to Welspun

INDIA

Leighton Holdings announced on 29 December that its subsidiary Leighton International had reached an agreement to sell a 35 per cent share of its Indian operations to Welspun Corporation, a leading diversified Indian conglomerate.

Leighton Holdings CEO-elect

David Stewart clarified this as a move to build a 'strategic partnership' to capitalise on huge Indian infrastructure opportunities.

"We have been working successfully in India for 7 years and see the transaction as very important in taking our Indian business to the next stage of its development. Having a local

partner clearly provides greater access to the market, particularly when Welspun has such a complementary portfolio of businesses," said Mr Stewart.

Welspun Group has a presence in infrastructure, oil and gas, steel, pipes and textile sectors. It operates in over 50 countries and last year had revenues totalling USD 1.6bn.

Setting the standard for blasting competence

BLASTING QUALIFICATIONS

“A new set of blasting qualifications for shotfirers and explosive engineers should be available through the Mineral Products Qualification Council from as early as March,” said Ben Donnachie, internal verifier and Assessor of the BAM Ritchies Division of BAM Nuttall.

Originally intended to be made available from December 2010, the approval process was slowed by a glitch in the regulatory authority’s website that prevented ConstructionSkills from uploading the required endorsements.

There has never been a set of UK-wide industry recognised qualifications for blasting in construction or tunnelling. However, following an industry review to gauge interest in the creation of such a course, the robustly positive results from institutions such as ConstructionSkills, Proskills, the Institute of Explosives Engineers and also TunnelSkills, has spurred its creation and led to the first meeting at BAM Nuttall Training Centre, Halesowen on 9 September 2010.

According to Donnachie, TunnelSkills expressed its interest in the scheme to promote improved competence in the tunnelling industry by setting competence standards utilising qualifications based on appropriate National Vocational Qualifications based on National Occupational Standards.

The primary goal of these qualifications has always been to become a standardised method of demonstrating competence. Two requirements under The Construction (Design and Management) Regulations 2007 made it compulsory for all work to be carried out by a ‘competent’ person:

- BS6164:2001 - Code of practice for safety in tunnelling in the construction industry
- BS5607 - Code of practice for the safe use of explosives in the

construction industry. A competent person is defined in the code as a person with sufficient training, experience, knowledge and other qualities to enable them to undertake the duties assigned to them.

There have been many discussions as to the best route to allow us to demonstrate competence. For many years the NVQ has been generally accepted as the preferred method of workplace assessment. However due to various sector requirements a cross sector standard has been elusive – until now.

The introduction of the Qualifications and Credits Framework (QCF) in England, Wales and Northern Ireland allows existing units to be shared with other Awarding Organisations to produce sector specific qualifications.

This means that the current Blasting Operations QCF units can be used to provide suitable blasting qualifications for Construction, Tunnelling, Demolition and Construction Diving.

“The new group of qualifications has been created to be a pathway of the existing Blasting Operations suite of qualifications and will be endorsed with Tunnelling,” said Donnachie.

He added, “These blasting qualifications are aimed at shotfirers and explosives engineers. Current in-house training courses could be assessed to National Occupational Standards and provide an industry recognised and transferable qualification.”

The industry is familiar with NVQ Levels 1 – 5, with Blasting Operations set at NVQ Level 3. The QCF recognises achievement through awards of credit for units and qualifications and is more responsive to employer and learner needs.

All qualifications in QCF will have standardised titles, which determines the level, size and content.

The qualification title will determine the content.

Qualifications Available

- **Shotfirer** - Level 3 NVQ Diploma for Shotfiring in Construction (QCF)
- **Explosives Storekeeper** - Level 2 NVQ Certificate in Explosives Storage for Construction (QCF)
- **Blast Designer** - Level 5 NVQ Diploma in Blast Design for Construction (QCF)
- **Explosives Engineer** - Level 5 NVQ Diploma in Shotfiring

Supervision for Construction (QCF)

- **Bulk Explosives Truck Operator in Tunnelling** - Level 2 NVQ Diploma for Bulk Explosive Truck Operations in a Tunnelling Environment (QCF)

Donnachie finished by saying, “The standardisation of shotfiring qualifications for Construction is long overdue and will provide sector Shotfirers and Explosives Engineers with transferrable qualifications. This will increase the professionalism of individuals, improve health & safety standards and reduce accidents within the blasting industry.”

The working group on this project included:

Kevin Bennett *BAM Nuttall*;
Ben Donnachie *BAM Ritchies*;
Brian Earnshaw *TunnelSkills*;
Steve Goodgroves *SPG Safety*;
David Hudson *Mineral Products Qualifications Council*;
Malcolm Ingray *Institute of Explosives Engineers*;
Phil Robinson *EPC-UK*;
Andy Rotherham *Proskills (SSC)*;
Phil Smith *Health and Safety Executive (Explosives)*;
George Swann *Construction Skills (SSC)*;
Andy Watson *Mines Rescue Services*.

Alex Conacher

Below: The table shows the qualification comparisons with QCF (England, Wales and Northern Ireland), SCVQ (Scotland) and the old NVQ. The Blasting Operations suite of qualifications is set at NVQ Level 3

Qualifications framework – A comparison			
QCF level	SCVQ level	NQF & SVQ level	Traditional academic equivalents
8	12	5	PhD
7	11		Masters
6	10		Honours Degree
5	9	4	Ordinary Degree
4	8		HND
3	7	3	HNC
	6		3 “A” levels
2	5	2	3 GCSE A – C
1	4		3 GCSE D – F
Entry 3	3		Entry
Entry 2	2		
Entry 1	1		

Note: This a guide only



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What lies beneath the Mediterranean

Despite economic instability in the southern European and Mediterranean region, ambitious projects are currently being constructed, moving forward at their own pace or, in the case of the Sicily to Tunisia crossing, a pipe dream under consideration. Alex Conacher explores projects in the region

Southern Europe and the Mediterranean have suffered worse than most in the wake of the global recession. Hefty mobilisation of Chinese resources has seen 'debt purchasing' of Spanish bonds since the implosion of the housing boom, while Stricken countries like Greece and Italy provide ammunition for Eurozone sceptics clamouring to be the first to deliver a crushing 'I told you so'.

Not everything is so bleak, however as the tunnelling industry endures and there are still a great many projects ongoing in Europe. Notable among these are the Italian metro projects (see also page 26) and the impressive Marmaray crossing under the Bosphorus. Even projects that

some consider 'pie in the sky' refuse to finally keel over—the world-beating Sicily to Tunisia tunnel and the crossing under the Straits of Gibraltar still have supporters crowding around the drawing boards.

1) Vitoria – Bilbao – San Sebastian rail tunnel

The USD 1.7bn Vitoria – Bilbao – San Sebastian rail tunnel project in the Basque region of Spain requires the construction of a series of tunnels. The longest, the Albertia tunnel runs for 4.8km, the Udalaiz tunnel at 3.2km, the Zaratamo at 2.7km, the Induspe at 2.3km, the Galdakao at 1.8km, the Ganzelai at 1.4km and the Luko at 970m. EPC was awarded to Tecsa and Altuna y Uria.

2) Mont d'Ambin Base Tunnel

This France-Italy rail tunnel will be one of the longest in the world, measuring at 51km, when it is completed. The French and Italian governments, as well as the European Union are providing the funding for this USD 9.5bn project.

3) Milan metro

The USD 3.5bn Milan metro extension project will feature tunnels on lines 1 to 6, with two on line 3. The approx. 30km of tunnels will be excavated by TBM by EPC contractor, Azienda Trasporto Milanese. The client is Azienda Trasporto Milanese.

4) Naples metro

The Naples metro is smaller than that in





Milan. Requiring only two tunnels totalling 19.2km the cost is around USD 2bn. The client is the Ministry of Infrastructure and Transport.

5) Rome metro

Metro expansion in Rome is also on behalf of the client; Ministry of Infrastructure and Transport. A total of six TBMs are in use in the Eternal City and funding is shared between the Government of Italy, the City of Rome and the Lazio region.

6) Sparvo tunnel

Herrenknecht have constructed the world's largest TBM to date, at 15.62m, for the contractor, a JV of Vianini Lavori, Toto Costruzioni Generali and Profactahas. The 2.5km tunnel will cost USD 432M and will form part of the A1 highway link between Florence and Bologna. Excavation will commence in May, finishing at the end of 2013.

7) Markovec Tunnel

In Slovenia the Markovec tunnel project is underway and should be finished in 2013. The USD 95M project for the construction of a 2.1km tunnel also requires extensive safety equipment, including microwave vehicle detectors.

8) Athens metro extensions

Current projections suggest that work on the Athens metro line extensions should be completed by 2016. Specialist, state-owned metro construction company Attiko Metro is carrying out work.

9) Suez Canal tunnel

The proposed Suez Canal tunnel in Port Said, Egypt, will feature two car passages and one rail. Put to consultants by the Egyptian Ministry of Transport, it is designed to be 19km and will reduce congestion in the port by providing an alternative to an existing route. Cost projections have hit USD 1bn.

10) Strait of Gibraltar crossing

A dream of many years, the tunnel to link the Pillars of Hercules would be a connection between high-speed rail networks in Morocco and Spain. The double-tracked railway tunnel would run for 39km with 29km under the sea. Projected costs of around USD 14.7bn would be met by the governments of Spain and Morocco.

11) Marmaray Project

The Marmaray Project, which spans two continents and links the west and east

sides of Istanbul, will be capable of carrying 70,000 passengers per hour across the Bosphorus Strait. Costing around USD 3.5bn in total, the 13.6km of tunnels include a 1.4km immersed tube, which required special engineering for deep-sea pressures put on the segment seals.

12) Sicily to Tunisia crossing

This is the largest project on the map. Another tunnel of dreams etched out on the drawing board. This USD 28bn project would, if ever constructed, become by far the longest rail tunnel in the world at 155km, smashing the Gotthard Base Tunnel by around 100km. It also envisages the construction of four artificial islands along the route. Tourism is also intended to partially fund the project. The Government of Italy is the planning authority.

13) Barcelona metro

A JV of FCC and Dragao is constructing line 9 of the Barcelona metro project using TBMs ranging from 9.4 to 12m in diameter, each individually adapted to suit the aggregate geology in their respective tunnel sections.

14) Prado Sud tunnel

The USD 283M, 1.5km Prado Sud tunnel in Marseille will form an extension of the Prado Carenage tunnel. The tunnel is being excavated by a 60/40 partnership of Vinci and Eiffage.

15) Mostoles to Navalcarnero rail line tunnels

This project in the west of Madrid involves the construction of two tunnels each of 3.8km. It costs USD 325M and TBM excavation is underway. This environmentally conscious undertaking will reduce noise and air pollution as well as cutting congestion.

16) Thessaloniki Metro : Line 1 tunnel

Some 9.6km of automatic rapid transit network lines are to be built in the northeast of Greece. This futuristic project will cost around USD 1.5bn and will be constructed using an EPB shield, as well as cut and cover for some sections. The EIB has identified the project as one that will improve quality of life in the region and has partially funded it.

17) Mavi Blue Tunnel

This Turkish tunnel project commissioned by the General Directorate of State Hydraulic Works will boost drinking water and irrigation capacity in the Konya province. The 18km, 4.88m diameter tunnel

will be completed by the end of 2012.

18) Second Bosphorus crossing

The smaller of Istanbul's two Bosphorus projects - the larger being the Marmaray - the crossing will, all told, take 30 years to complete, of which less than five will be spent on construction. The project is valued at USD 1.2bn.

19) Algiers Metro

The second extension project of Algiers Metro Line 1 is part of an extensive investment program by the Algerian government. The 3km, NATM-constructed tunnel has a combined cost of 120M with the bridge that is also required.

20) Cairo metro

The 34km of metro for the Cairo line 3 will be finished in 2013. Requiring 25 underground stations to be constructed by contractors including Oci, Arab Contractors, Vinci and Bouygues. Cost is projected at around USD 3.7bn.

21) High-speed Jerusalem-Tel Aviv rail link

This long awaited replacement for the Jaffa-Jerusalem snail rail began design work in 2000 and is currently in its third stage of construction. Amy-metom is prime engineer on this predominantly tunnelled stage, with 36km of underground works.

22) Gurpinar Wastewater Tunnel

One of several new wastewater tunnel projects in Istanbul. This USD 645M project to build a 5.3km tunnel is the longest. It also requires automatic fire and ventilation systems. The presence of Lovat technicians was required for the initial drive.

23) Pointe Pescade Collector, Stage 3

In the northern-central part of Algiers, a micro-tunnelling project to install an almost 3km new sewer by pipejacking is underway. Tunnelling has yet to begin. Denys is the microtunnelling contractor.

24) Egnatia Odos tunnels

The EUR 6.77bn (USD 9.03bn) Egnatia Odos, which translates as Roman Road, is an ambitious motorway of approximately 670km. Requiring a total of 76 tunnels with a total length of around 100km to connect the two coasts of northern Greece.

25) Souk Al Juma Utilites Package

This USD 400M project in Tripoli, Libya to improve the city's sewers will be constructed using a combination of TBM and drill and blast techniques. ▀



Thessaloniki challenges

Challenges of archaeological discoveries, sensitive structures, geology and worksite availability face tunnellers on the Thessaloniki metro in Greece. Report by Patrick Reynolds

With more than half of the 7.7km long single-track, twin tube tunnels bored for the first, or 'base', metro line in northern Greek coastal city of Thessaloniki, the first TBM is due this month to reach Efklidi station. Tunnelling resumed after a half-year standstill in August 2010, the hold-up having been caused by archaeological discoveries and limited availability of work sites.

But these were not the first programming challenges for the tunnelling works on the 9.5km long base metro line, which will have driverless trains – similar to the system in

Copenhagen. Earlier, the TBMs were faced with passing below a weak mosque structure, through areas of poor ground and overcoming unexpected hurdles of the wrong reinforcement in diaphragm walls that were to be bored through at partly-built stations.

However, since the TBM restarts last August, and despite a refit for a slight change in geology, the rate of progress achieved by the shields has picked up. They have been passing more partly-built stations and ahead must hold before breakthrough at Efklidi station, and later relaunches for the remainder of the bores to be done.

Originally, before the various challenging delays, it had been anticipated that the line would have come into service by the second half of 2010. Despite the setbacks around the underground works, though, the task of tunnelling has progressed relatively well.

When completed, the base metro line is to carry 18,000 passengers per hour in each direction – north and south – with the frequencies of the driverless trains giving intervals of 90 seconds between services. Presently, it is expected that the new line will be commissioned in 2013.

Once completed, the north-south running metro line is to be extended in stages – farther north with two branches, and a branch to the international airport in the south.

Procurement & Plan

Thessaloniki base metro line is being developed by Attiko Metro, based in Athens is also working on further development of the subway network in the capital.

In 2006, Attiko Metro awarded the design, construction and commissioning contract for Thessaloniki base line metro to a JV of Aegek (28.76 per cent), Impregilo, (26.70 per cent) Ansaldo Trasporti (21.72 per cent), Ansaldo Breda (15.60 per cent) and Seli (7.21 per cent). The contract is valued at Euro 958 million, and includes construction of the twin tunnels, 13 stations, control centre, administration and services buildings and depot, and trains.

Left: Location map of Thessaloniki metro showing Base Line and planned extensions

A separate JV, comprising two of the JV partners – Seli and Aegek – is undertaking the underground works in a subcontract, on a 60:40 basis. In total, the tunnelling and other civil engineering works being undertaken by the subcontracted JV plus Impregilo accounts for just over half of the main contract value.

The base metro line will have 13 stations. From north to south, they are: N. Sid. Stathmos, Stathmos, Dimokratias, Venizelou, Aghia Sofia, Sintrivani, Panepistimio, Papapfi, Efklidi, Fleming, Analipseos, Patrikiou, Voulgari and Nea Elvetia.

Along the alignment, geology includes clay, sandy clay, and sand with cover of up to 27m. Sections of ground along the route are very weak. However, combinations of tunnelling below historic buildings and the potential for archaeological discoveries were recognised to be among the prime challenges on the project.

Tunnelling works commenced in early 2009 and completion is expected in late 2012, due to a range of delays related to the type anticipated, and other construction and access hurdles. Previously, it had been expected the tunnelling work would be finished by 2010.

The 5.3m i.d. running tunnels are being bored by a pair of 6.12m diameter Herrenknecht EPBMs, each with maximum cutterhead thrust of 40,000kN, power of 1000kW and cutterhead rotational speed of up to 4 rev/min. Seli has provided the back-ups for the machines. The shields will always work in full EPB mode, in pressures ranging from about 1.7-1.8 bar to 2.5 bar, and with full chambers.

The precast concrete lining is assembled from 300mm thick segments to be bolted (5 + 1) rings, each 1.5m long. The excavation and lining system includes a two-component grouting system.

Tunnelling works are performed four days per week (Monday-Thursday) with maintenance on Friday mornings. On the working days, the crews work three shifts.

Tunnelling

Assembly of the first TBM was undertaken in late 2008, some months after originally envisaged. The shield was launched in





January 2009 to bore the south tube of the Thessaloniki base metro line. The second machine was launched from the same 15m shaft to drive the parallel north bore in April 2009.

The south TBM drive – the tube on the right when looking southward in direction of the bores – has remained the lead shield of the pair, always a few hundred metres ahead of its sister machine. By mid-January this year, the machines had been in the ground for almost two years and had advanced 4.2km and 3.9km, respectively.

A range of challenges have been faced on the overall construction works with impacts on the tunnelling progress and causing the programme for the drives to be extended. Despite those impacts, the tunnelling works have gone relatively well.

On their first drives, which were almost 3km long, the TBMs were to pass the partly-constructed sites at stations (Dimokratias, Venizelou, Aghia Sofia) without having breakthroughs into completed boxes – the first hole through would not come until Sintrivani, the fourth location to be reached by the machines.

Along these drives, the early challenges for the tunnelling works and advancing the TBMs included securing passage below the 15th Century, seismically-weakened Alkazar mosque, but also some difficulties with some recently-built parts of structures for the metro: unexpectedly, the wrong reinforcement – steel instead of fibreglass – had been used in a few diaphragm walls through which the TBMs would have to pass.

Resolving the construction problem with those diaphragm walls required extra time and work to overcome, but time and effort was needed for necessary remedial operations on the TBMs to deal with both tool replacement on the cutterheads and maintenance work needed. These works on the TBMs called for hyperbaric interventions, and, for example, in one week alone there were eight such actions needed, in pressures up to 1.7 bar.

Sintrivani station was finally reached in November 2009. By then, average daily progress rates for each machine was in the 13-15m range, excluding stoppages and only based on days of active excavation.

But it wasn't until August 2010 that the machines were re-launched, three weeks apart, on drives via more part-built stations to Efkli station. The lengthy standstill before the second drives could commence was the result of the combined effect of extensive archaeological works and discoveries at station sites, and limited availability of work sites. The

diaphragm walls and slab construction works are at varying stages of completion in most locations.

Drives ahead

As the drives proceeded into this section of

more difficult geology combined with old building stock, the cutterhead configuration of the TBMs was changed towards late 2010. Leaving the red stiff clay they had been boring through for about 2km to softer ground, the re-configuration of the

Below, top: Twin tunnel bores on Thessaloniki metro are more than half complete but many station works remain to be done **Below, bottom:** Two Herrenknecht EPBMs are driving the twin tubes at Thessaloniki metro





Left and above: Breakthrough at Sintravani station in late 2009. Boxes at earlier stations were not finished when passed

TBMs included removal the central cutters to replace them with central rippers. Some cutterhead openings were increased, which also resulted in lower thrust forces and torque for improved TBM advance, and good control of face pressure and EPB parameters.

Since the re-start of the machines in the third quarter last year, the average daily advance for each machine has been 15.5m, which has enabled them, together, to

complete more than 500m per month. The best week saw one machine cover 80m, with an advance of 22.5m on the best day.

The south TBM is due to arrive outside Efkli station – yet to be finished – at the beginning of February. The shield will be stopped for an estimated time of about a month for the station structure to be completed. Meanwhile, its sister TBM will have closed the gap and both machines will then be able to hole through into the

box station, around March.

Once departed from Efkli, the TBMs will have a further 3km each to bore via sites for stations where only early works are underway, including the immediate next on the line – Fleming and Analipseos, but where no excavations have yet taken place. The soft ground for the remaining drives is expected to comprise sand, silt and lower clay content (only 18 per cent) with groundwater pressure around 1.5 bar.

By mid-year the first of the TBMs is expected to be at Analipseos.

Below, top: The lead TBM was relaunched on the second drive in August 2010

Below, bottom: Ahead, the shields face softer ground, older structures and continued archaeological works around part-build stations.



Extensions

In the late 1990s, an effort to have the metro line developed under concession failed and by 2003 the procurement and funding approach had turned to employing both state and EU funding. There followed an extended procurement period that included a few stages before shortlisted parties bid and, finally, the contract was awarded.

Thessaloniki is now looking to have three extensions to the base metro line, as follows:

- Phase 1 extension – to extend the base line both to the east and west, with five stations over 5km to Mikra in the Kalamaria area to the east, and five stations over 5km to Efkarpa in the Stavroupoli areas to the west.
- Phase 2 extension – to extend the Phase 1 extension a little farther, from Efkarpa to PapaGeorgiou; and, extend the base line also west via a separate branch with three stations to Scholes.
- Phase 3 extension – to take Phase 1 further east, on an elevated section, via four stations to Makedonia airport. This section is still in planning.

Attiko Metro says it hoped to have the contract for the mostly underground Phase 1 extension to the Kalamaria area awarded in 2011. ▀



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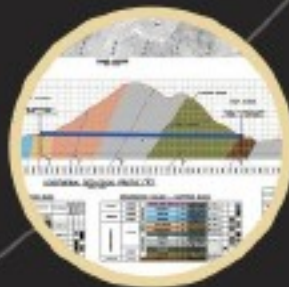
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Crossing the Bosphorus - again

As construction progresses on the record-busting Marmaray rail tunnel in Istanbul, financing is finally being put in place for a road crossing under the Bosphorus. John McKenna reports





Welcome to boom town. Istanbul's economy expanded by 5.5 per cent on a per capita basis, and employment rose an astonishing 7.3 per cent between 2009 and 2010.

The Washington-based Brookings Institution, in a joint investigation with the LSE Cities project, judged that Istanbul had beaten Beijing and Shanghai to claim the title of 2010's most dynamic city.

To maintain this astonishing economic growth rate, Istanbul must invest in what has for centuries been a mainstay of its fortunes – its role as a main transit

route for trade between Europe, the Middle East and Asia.

Investments designed to create new transit routes, or to alleviate pressures on existing ones, are coming thick and fast.

Turkey's largest transport project at the moment is Istanbul's USD 3bn Marmaray rail scheme, a project featuring the world's deepest undersea immersed tube underneath the Bosphorus, in addition to TBMs, NATM and cut and cover being used on other sections of the 13.6km tunnel (T&T October p20).

This project is due to complete in 2014, having passed the half-way point for

construction early last year.

Following on from Marmaray, Turkey's Ministry of Transport has awarded the contract for the USD 8bn Istanbul-Izmir motorway tunnel, which will include the world's second-longest suspension bridge, while tenders for construction of a third bridge across the Bosphorus and a third airport for Istanbul are expected to be invited in the coming year.

However, being the world's most dynamic city, Istanbul is not ending its tunnelling ambitions with the Marmaray project.

Financing is currently being finalised for a road tunnel to be built under the





Project financing at a glance

Project name	Istanbul Strait Road Tunnel
Location	Underneath the Bosphorus, on an alignment south of Marmaray rail tunnel
Description	A Build-Operate-Transfer financing of a submarine duplex tunnel and connecting roads
SPV	Eurasia Tunnel Operation Construction and Investment (ATAS)
Sponsors	Yapi Merkezi; SKEC
Awarding agency	Ministry of Transport's General directorate of railways, harbours and airports (DLH)
Project duration	30.5 years
Construction	Four years, seven months duration
Total project value	USD 1.2 billion
Total debt	USD 800 million – USD 1.1 billion
Multilateral lenders	EIB EBRD
Export Credit Agencies	K-EXIM K-SURE
Commercial Banks	Garanti Bank ING Bank Isbank SMBC Standard Chartered; WestLB Yapi Kredi
Legal advisers to lenders	Clifford Chance; Fidan & Fidan
Financial adviser to sponsor	Unicredit
Environmental impact assessment	Environmental Resources Management
Date of financial close	Expected Q1 2011

Bosphorus. This project is expected to go even deeper than Marmaray, as its main submarine section is planned to be built using TBMs rather than immersed tubes.

Scheme outline

The project, officially known as the Istanbul Strait Road Tunnel, will connect Kazlıcesme region on the European side with Goztepe road crossing on the Asian side. The tunnel will be a two-deck two-lane link for light vehicles only, including a 3.3km undersea section and 2.1km of connecting roads, with tolls on the European side of the tunnel.

Following a tender launch in 2007, two

consortiums made offers for the Build Operate Transfer (BOT) concession contract for the project.

A Turkish-French consortium formed by Cengiz, Makyol, Dogus and Vinci offered the lowest bid and a concession period of only 19 years - six years for investment and construction, 13 years for operation.

However, they were beaten by a Turkish-Korean joint venture proposing a 30.5 year concession allowing four years, seven months for construction and 26 years for operation.

The Turkish-Korean JV were awarded the concession in summer 2008 by the Ministry of Transport's General directorate of railways, harbours and airports (DLH). The JV comprises Turkey's Yapi Merkezi and the South Korean Engineering Companies (SKEC) consortium, which consists of Samwhan, Hansin, Namkwang Engineering & Construction and Kukdong.

Since the award of the concession the JV has been carrying out advanced engineering studies, geological work, and designing the scheme.

It will have two levels of traffic and two lanes per direction. Each level will be dedicated to one direction of traffic. Located on an alignment south of the Marmaray tunnel, like its predecessor the project is expected to comprise several tunnelling methods such as advanced TBM technology for the parts under the Bosphorus and open cut and NATM for other parts.

The crossing will have a total length, in three sections, of 14.6km. The central submarine duplex tunnel section, 5.4km long, will be operated under a 30.5 year-long concession, while the non-tunnel road sections at each end will be returned to the public authorities on construction completion.

The 5.4km central section includes connecting roads. The length of the TBM tunnel will be 3.34km, with internal diameter of 11.4m and external diameter of 12.4m. The NATM cross-section will be 15m wide and 22m high, whereas the open cut cross-section will be 10m wide and 6m high.

The group has also completed an environmental impact assessment, carried out by Environmental Resources Management. The firms involved in the project have declined to release maps or diagrams until all financing has been secured.

Financing

In addition to the designing the scheme, much of the work over the past two and

half years has been focused on getting the financing in place.

The project is being financed as public private partnership, with the bulk of the funds likely to come from private sector equity, provided by the sponsor firms, and debt provided by a combination of commercial and development banks.

Upon award of the concession the Turkish-Korean JV formed a special purpose vehicle (SPV) company, or concessionaire, to arrange an arm's length project financing for the scheme on behalf of the sponsors.

The project SPV, Eurasia Tunnel Operation Construction and Investment (ATAS), is making a total investment of USD 1.2bn.

The total debt package involved is likely to range anywhere between USD 800M and USD 1.1bn, and will be confirmed when the project reaches financial close, expected by the end of the first quarter of 2011.

As with Marmaray, the European Investment Bank (EIB) will be making a sizeable loan commitment to the scheme – it lent EUR 450M (USD 610M) to Istanbul's rail tunnel and is now considering lending up EUR 250M (USD 340M) to the road tunnel scheme. The European Bank for Reconstruction and Development (EBRD), which focuses on financing projects in Eastern Europe, Russia and Central Asia, is also likely to lend to the scheme, with its investment decision due February.

Also like Marmaray, where the Japan Bank for International Cooperation (JBIC) supported the scheme thanks to the involvement of Japanese contractor Taisei, so has the prominent role of SKEC on the road crossing ensured support from South Korean financial institutions.

Both K-Sure (Korea Trade Insurance Corporation) and KEXIM (Export-Import Bank of Korea) are expected to offer either direct lending or credit guarantees for debt provided by commercial banks.

The commercial banks lending to the scheme are understood to be a mixture of local and international banks, including: Garanti Bank; ING Bank; Isbank; SMBC; Standard Chartered; WestLB; Yapi Kredi.

As well as securing debt for the scheme from the above banks, ATAS is also hoping to attract equity partners and is in discussion with various infrastructure funds over potential investments.

Unicredit is acting as financial adviser to ATAS and structuring the deal, Clifford Chance is the lenders' legal adviser, while local legal advice comes from Fidan & Fidan.

Financial close is expected by the end of March at the latest, paving the way for early works to begin later this year. ■



GAUTRAIN SITE DEMOBILIZATION

Bombela Civils Joint Venture consortium (civil contractor to the Gautrain), consisting of Bouygues Civil Works, Murray & Roberts and the Strategic Partners Group (SPG) has reached the point of site demobilization. as a result the equipment / plant are available:



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Refurbished Shotcrete Robot PUTZMEISTER: Model PM 407



Refurbished Shotcrete Robot PUTZMEISTER: Model PM 500



Refurbished NORMET Himec 9915 B.A

LIEBHERR Tower Cranes 280 EC-H 12

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The Italian jobs

Tunnelling is booming in Italy, with four major projects under construction and a further eight at the tender, design or financing stage. John McKenna reports

Italian contractors, it would seem, are currently enjoying la dolce vita. Tunnel construction is as much a part of Italian life as Berlusconi's love affairs.

There are four major projects currently under construction that include significant tunnelling contracts, plus another eight that are at the tender, design or financing stage.

That there are so many schemes involving tunnelling work is of little surprise to Ashurst partner Carloandrea Meacci. The firm's Energy, Transport and Infrastructure department in Milan has been engaged as a legal adviser on several recent project financings for schemes where tunnelling is a key part of the construction package.

Variante de Valico

The most significant project being built is the EUR 3.2bn (USD 4.3bn) widening of a 62.5km section of Italy's A1 between Bologna and Florence and construction of a 37km bypass, known as Variante di Valico (variation of crossing) through the Apennine mountains.

Stretching from La Quercia in the north to Barberino in the south, the Variante di Valico project includes 18 tunnels with a total combined distance of 17.9km.

Tunnelling work on the scheme has been split into six packages. The project's latest milestone came on the base tunnel package, which holed through in December 2010. Part of Section Badia Nuova-Aglio (11.2km) of the Variante di Valico, the base tunnel is the largest highway tunnel in Italy with 8.6km length and 180 sq m section for each carriageway. The project is being carried out by Todini Costruzioni Generali (Salini Group) and will complete in 2012.

The tunnel route crosses a rock mass that belongs to the Tuscan formation (Monte Cervarola) and the Ligurian formation (scaly clays). To tackle the geology, drilling and blasting was used for half of the drive and mechanical means for the other half. In Monte Cervarola sandstone, systematic drilling and blasting was used. In the scaly clay, the tunnel face was pre-reinforced with fibreglass pipes injected with grout prior to excavation with a hydraulic breaker.

Tunnelling in the Monte Cervarola rock





mass was executed with two Tamrock Axera T12 Data jumbos. Shotcrete was sprayed with CIFA CSS PAS 307 pumps. In the scaly clays, excavators Cat 345 BII and Hitachi ZAXS 350 equipped with breakers Rammer G 100 and G 88 were used. For tunnel support, bolts, twin IPN 180-220 steel ribs and fibre-reinforced shotcrete were installed. Other means used were Dieci Pegasus platforms, Atlas Copco compressors, CTM generators, FlaktWoods ventilators and CIFA formwork.

The other package on the project to hit the headlines recently was the Sparvo project, on which the world's largest TBM, a 15.62m diameter Herrenknecht Earth Pressure Balance Shield, was accepted by the JV contractor Vianini Lavori /Toto Costruzioni Generali/Profacta in December.

The giant TBM is currently in the process of being dismantled and shipped from Herrenknecht's Schwanau factory to Italy, enabling final assembly to commence on site in February. It will start excavation of the first tube near Florence in a northerly direction in May 2011 with plans for the new route to open by the end of 2013.

The twin tube Sparvo tunnel will set new record in mechanised tunnelling. At 2.5km long, each tube includes a two-lane road and a third emergency lane.

Loose soil containing explosive firedamp is anticipated along the 5km stretch. In order to achieve a high degree of safety and swift tunnelling performance, the building contractor opted for an EPBM.

The 4,300t machine with its 12,000kW cutterhead power will set a new record in mechanised tunnelling as far as the drilling diameter is concerned.

Lombardy Tunnels PPP

The other main road tunnel project taking place is not so much a single scheme, and doesn't involve any new construction – it is a EUR 150M (USD 205M) programme of restoration to 96 tunnels in the Lombardy. Run as a public private partnership by Italy's national highway authority ANAS, the scheme is continually letting out small packages of work – the most recent being on the refurbishment of the SS237 between Tormini and Barghe.

Milan Metro Line 5

On the rail side of things there are two key metro schemes currently under construction, one in Italy's capital and one in its financial centre.

Milan's M5 line will run north for 5.6km

from Garibaldi main rail station to Bignami with intermediate stations at Isola, Zara, Marche, Istria, Ca'Granda, Bicocca and Ponale – from where the shield has already been relaunched on its southbound run after the first intermediate breakthrough.

At Garibaldi and Zara the M5 line will interchange with the metro lines M2 and M3. The line is to come into operation in two stages: the Zara-Bignami section by March 2011; and, the final, 1.25km long Garibaldi-Zara section by May 2012.

The Design, Build, Finance Operate concession for the project was awarded to a consortium of Astaldi, Ansaldo, Torno, Alstom and ATM for 32 years, including a five year construction phase. Design and construction of the line will cost some USD 740M and it is Italy's first major urban transport project to use project finance.

The financing, signed in December 2007, totalled USD 817.35M. Debt and equity contributions broadly split 50:50 – total equity is USD 412M, while total debt is USD 405.35M. The debt package breaks down in to a 23-year term loan of USD 269.16M, a construction "bridge" loan of USD 58.83 million to support spending during the construction period, a USD 29.42M standby facility and a USD 14.71M working capital facility – both with tenors of 23 years to support cost overruns at any time during the concession – and a VAT facility of USD 33.24M.

The debt was provided by: Societe Generale, Dexia, WestLB and Mediobanca.

The new line with automatic, driverless trains is eventually to be extended to Monza, it is proposed, with four intermediate stations. There is also a proposal on the cards for a westward extension from Garibaldi to San Siro with nine intermediate stations.

Lovat's EPB shield TBM, despatched to tunnelling subcontractor Ghella, is advancing well in its drive on the scheme. The 9.4m diameter mixed face shield is driving more than 3.5km through gravel, sands and some weak silts with cover of 8-12m. The drive, in the north of the city, is mostly above the water table.

Fitted with ripper teeth and scrapers, the cutterhead has power and maximum torque of 2,700kW and 24,940kN at 1rpm, respectively. Tunnel lining is 8.15m i.d., 350mm thick with rings 1.5m long.

Rome Metro Line C

Rome's Metro Line C is among the most significant and challenging infrastructure



Left: Rome Line C site by Monumento Nazionale a Vittorio Emanuele II

projects underway in the world today.

Comprising twin 17.6km tunnels beneath the ancient city, construction of the project is being carried out under a turnkey contract by the joint venture Metro C (formed of Astaldi, Vianini Lavori, Ansaldo Trasporti-Sistemi Ferroviari, Cooperativa Muratori e Braccianti di Carpi, Consorzio Cooperative Costruzioni).

The JV is using four identical Herrenknecht EPB-TBMs, with cutter head diameters of 6.71m and a 10.7m shield length. The four TBMs have all completed their main drives, the most recent being the fourth TBM S-479's completion of the 2.8km Malatesta-Pozzo drive in July 2010.

The two machines S-409 and S-410 successfully reached the first milestone as October 2009, have been dismantled and were launched for their second drives late last year. On these drives the TBMs will tunnel the routes T3 and T4 from Malatesta to close to Venezia station.

On this stretch the machines will cross beneath the famous Colosseum building with an overburden of 30m.

The design of the four identical Earth Pressure Balance Shields (6,690mm diameter) for Line C is specifically adapted to the geological conditions of the route. An opening ratio in the cutting wheel of some 40 per cent allows a better flow of material into the excavation chamber, thus reducing clogging in the openings.

The high opening ratio also increases the contact pressure of the tools which provides for a better penetration. The cutting wheel, which is rotatable in both directions, is equipped with a total of 100 scraper tools, 16 buckets and an overcutter for soft ground. The discs can be accommodated in 13 casings and can be exchanged for rippers to suit the geology.

Two rotors at the cutting wheel and four stators at the pressure wall provide for a

good mixing of the excavated material in the excavation chamber together with the cutting wheel arms, and a good consistency of the material is obtained by injecting foam.

With the help of conditioning, the torque required and wear-and-tear can be reduced to a minimum. The drive's torque of 7,027kNm with 1.46 rpm is generated by nine hydraulic motors. The four axial piston pumps for the hydraulic motors are driven by four 400kW electric motors.

The shields are designed for a maximum pressure of 5 bar and are equipped with 19 double cylinders which generate a thrust force of 50,558kN. The shields are additionally equipped with two joints. One joint is an active control joint between front shield and centre shield, and the other is a passive joint between centre shield and tailskin. The two joints allow a narrow horizontal radius of a little as 150m.

The machines are also equipped with a bentonite control system to secure a constant pressure in the excavation chamber even outside working hours. If the predefined pressure in the excavation chamber falls, a pressure regulator automatically feeds bentonite from pressure tanks into the excavation chamber.

For the filling of the annular gap between soil and ring segment the so-called bicomponent system is being applied instead of filling the gap with conventional mortar and thick-matter-pumps. The bicomponent system involves pressing into the annular gap a special mortar mixture (component A), and the accelerator (component B) through six openings at the tailskin end with the help of six eccentric screw pumps. After mortar and accelerator have mingled, the mixture becomes solid within a few seconds. This avoids subsidence which can occur, for example, if the mortar hardens too slowly.

The tunnel lining is consists of 300mm

thick precast reinforced concrete segments with an internal diameter of 5.8m. Each prefabricated ring is 1.4m long and has six main segments and a key. The rings are of universal double tapered type and fit 19 possible different positions depending on the radius of curvature to be obtained. Segments are cast in a prefabrication plant by using a fixed formwork installation for concrete steam curing.

In total, Line C will be 25.5km long including 17.6km underground and with a total of 30 stations.

Coming up

Rome is also planning an extension of its Metro Line B, and a new metro Line D. However, both are being financed as PPPs and are stuck in the financing stage due to cost concerns and land acquisition issues.

Meanwhile in Milan bidding in December closed on the USD 2.2 billion Milan Metro Line 4 PPP, which will be a 14.7km track from the western suburb of Lorenteggio to Milan's city-based airport, Linate in the east. There are two bidders for the scheme – Impregilom and a JV of Condotte, Pizzarotti and RATP.

Also in Milan, financing is in progress for the USD 280M extension of Line 5 by 5.6km from Garibaldi station located in the centre of the city to the northwest suburbs, with ten banks agreeing to lend to the scheme in December 2010.

On the railways, tunnelling work on both the Catania railway extension and the dualling of Genoa-Ventimiglia line have both been recently tendered.

And on the roads, Impregilio has won contracts for two major schemes.

The Milan Outer East Orbital is a EUR 1.5bn (USD 2bn) project that is being privately financed under a 50 year concession. It is a 33km new toll road linking the Milan-Venice A4 motorway and the Milan-Bologna A1 motorway between Agrate Brianza and Melegnano respectively. The project will comprise some 23.6km of embankments, 5.5km of cuttings, 1.8km of viaducts and some 2.1km of tunnels.

The Lombardy 'Pedemontana' motorway meanwhile includes 13km of tunnels. The project comprises construction of the first section of the Como and Varese orbital roads and of the link between the A8 and A9 motorways (from Cassano Magnago to Lomazzo). Construction work includes approximately 47km of motorway and secondary roads. Impregilio's work is the first contract awarded on what is a EUR 4bn (USD 5.5bn) privately financed PPP scheme. ▀

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Algiers pipejack

Belgian contractor Denys is preparing a series of pipejack drives for the latest phase of the sewerage improvement scheme along the bay in Algiers. Report by Patrick Reynolds



Like many major cities, Algiers is investing to improve its wastewater and drainage network. The key, common strategy for the many projects underway internationally in coastal cities is to construct larger sewers that will intercept the myriad of smaller tunnels that often drain to the sea, and the Algerian capital is no different.

Within the next couple of months, contractor Denys is expected to commence pipejacking for a sewer project that will be the latest stage in construction of the large-scale wastewater interceptor being built in Algiers. Preparatory works, including final stages of shaft construction, are underway to enable contractor Denys to build this almost 3km long section of new sewer in the heart of the city, in the northwest section of the Bay of Algiers.

The microtunnelling project will jack concrete pipes below the built-up and industrialised coastline, passing below roads, railways and a number of buildings, though always above groundwater level. Denys will work from two launch and two reception shafts for the project. The excavation work along a north-south alignment is expected to take approximately one year to complete.

The almost EUR 17M (USD 22.7M) sewerage project is the third phase of a five-stage 'Collecteur Pointe Pescade' scheme being constructed to improve the wastewater collection and sewerage system performance. The entire scheme will be 25km long to drain flows to southwards from the west arm of the bay, and then southeast inland, to the existing treatment works in Bariki, beyond the most urbanised area.

Planning and procurement

In the west arm of the bay, the third stage of the sewerage project extends from coastal part of the Bab El Oued area, near the Rais Hamidou area, at its north end to pass the Casbah and then, at its southern end, terminates in the Tafourah area. With the built-up terrain sloping eastwards towards the bay, the alignment of the sewer runs closest to the coastline and below the main transport routes.

The client for the scheme is the department water authority for the city – Direction de l'Hydraulique et de l'économie de l'eau de la Wilaya d'Alger. The client undertook the preliminary design work for the third phase project over 2007-8. Bids were called in mid-2008 and contract award was provisionally made in December 2008 to Denys. The award of the contract was finalised on 1

September 2009, and marks the first contract for Denys in Africa.

Stage 3 is being undertaken as an EPC contract with a bill of quantities, and the contract form of the Algerian Conditions of Contract according to the law of public works.

Local subcontractor Teixco is responsible for site investigation and shaft construction, using secant piles, for the microtunnelling works to be carried out by Denys. Site investigation was carried out in the third quarter of 2009, in the closing months to the contract award and being accounted for as part of the contract.

The initial programme for the works suffered some setbacks due to delays getting the necessary authorisations and difficulties with re-routing utilities near the proposed shaft locations. The detailed design work is continuing as preparations are made to receive the tunnelling equipment, once finally cleared from customs at the port, and then commence the main underground works.

Project plan

The new collector will be formed of a 1800mm i.d. concrete pipeline that will pass through an area of the city that is geologically difficult, said Denys, as it has both gneiss and schists bedrock but also some areas that were, historically, backfilled with clay and sand, and reclaimed from the sea, during the French colonisation era. Parts of the alignment are in the backfill and other sections pass through bedrock.

Additional complications come from the alignment passing below important areas and buildings and, of course, from the works being undertaken in congested, busy and industrious parts of the city. Running north, the alignment of the third stage of the interceptor starts at a shaft nominated P1 for the microtunnelling, at Rue d'Angkor, at Tafourah, near a port entry and the administrative centre of the capital. The shaft is also the north end of the completed Stage 4 of the overall scheme.

The sewer is then routed near government buildings, then buildings from the French colonial period of around 1870, and then the terrain rises with the tunnel then running deeper to pass below one of the city's oldest mosques (El Djeddid) and the Chamber of Commerce until an esplanade is reached. From there, the sewer enters its last leg, in the popular Bab El Oued district, to the existing pumping station on the Boulevard Emir Khaled. This northern part of the city was the most affected by the earthquake of 2003.

A tunnel inceptor was the only feasible solution investigated, and the main

parameters of adjusting the layout related to the number of starting and arrival shafts to satisfy the needs of tunnel curves, and accounting for existing structures – buildings and roads – for the micro-tunnel drives.

Four drives totalling over 2.7km are to be executed by pipejacking to install the interceptor, which will have a total of 11 shafts, or manholes. In total, between Lot 4 at the southern end and the existing pumping station in the north the total length of the new section of sewer, however, is almost 3km. The microtunnelling works are to be executed with two starting, or launch, shafts and two arrival shafts.

The almost EUR 17M (USD 23.3M) project includes all tunnelling and construction works, including supply of the reinforced concrete pipes which will be manufactured by Denys' sister company, Socea, at a rented industrial facility in Rouiba. Equipment is being transferred from Socea's manufacturing facilities for the project.

The Denys group decided on this approach for its bid as there is limited experience in Algeria for production of concrete pipes suitable for pressures placed by pipejacking procedures. The plant is to manufacture four pipes per day.

Works on the project also include:

- Construction of two new circular shafts of 13m i.d. with secant piles for the TBM launches and pipejacking. They are to be 9m and 17m deep, respectively.
- Construction of a new circular shaft of 6m i.d. and 8m depth, and modification of an existing shaft from a previous stage (Stage 4) of the scheme, to receive the TBM after drives.
- Modification of the existing pumping station on Boulevard Emir Khaled, at the north end, to be the third of the three arrival shafts required for the works.
- Construction of visiting chambers at the two launch and the three arrival shafts.
- Construct connections to the live sewers.
- Connect possible, but as yet undetermined, sea outfall pipes.

Denys' division manager for North Africa is Geert Heytens, the project manager on the contract is Kurt Mussche and Geert Goossens is technical project manager. The division manager for tunnelling is Dirk Derycke.

Tunnelling plan

The pipejacking is to be performed between five shafts constructed, or modified, for the microtunnelling works – shafts P1 – P5, which run from the southern end to the north in that order.



Shaft P1 will be a modification of the existing shaft that terminated Stage 4, where jet grout piling will be done. At the northern end of the sewer, shaft P5 will be constructed by modifying the pumping station.

Near the middle of the sewer, shaft P3 will be a new construction of 6m i.d. and 8m deep. All three shafts will function as receptions for the TBM.

At present, as Stage 4 works have yet to be completed by state contractor Hydrotechnique and the modification work

needed for shaft P1 will have to hold off.

The client has yet to decide how shaft P5 is to be realised, and there is the possibility, notes, Denys, that an extra 500m of sewer may be built. Shaft P3 is almost complete.

The large, launch shafts for the TBM and the pipejacking work – P2 and P4 – will be constructed near the rail station and at the esplanade on Boulevard Amara Mohamed Rachid, respectively. Shaft P2 has been finished, and P4 should be completed in late February.

Above: Shaft P4 is under construction near the northwest corner of the Bay of Algiers

Denys has planned the excavation sequence to be focused in the southern half, initially, and to be:

1st Drive: P2 – P3; length approx 728m; depth of cover 6m-7m.

2nd Drive: P2 – P1; length approx 715m; depth of cover 6m-7m.

3rd Drive: P4 – P3; length approx 788m; depth of cover 15m-20m.

4th Drive: P4 – P5; length – still under study; depth of cover 12m-15m.

Below: A Denys group company, Socea, will manufacture concrete pipes for the pipejacking, which will start around March at shaft P2



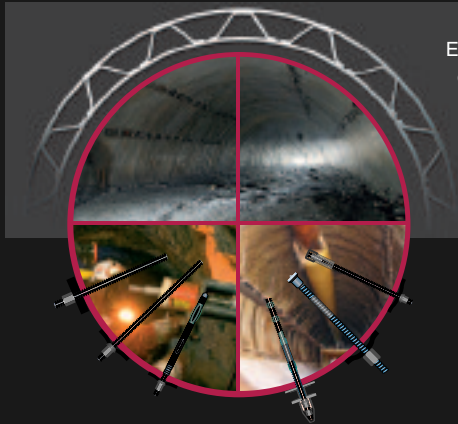
Detailed design has been completed and approvals received for the first drive, and work continues for the others with most expected to be approved shortly. The construction work is being executed under the supervision, for the client, of the Hydraulic works agency – Organisme de controle technique de la construction Hydraulique.

Tunnelling will be done using a Herrenknecht AVN 1800 TBM and intermediate jacking stations at about 100m intervals. Warmann slurry pumps will be used for the drive, and a Bauer slurry separation unit.

The project will have four Westfalia jacks capable of up to 200 tonnes of force, to give a total of 800 tonnes of the 3.3m long concrete pipes being jacked. Lubrication will be by bentonite injection. Blower ventilation will be employed, and a VMT guidance system.

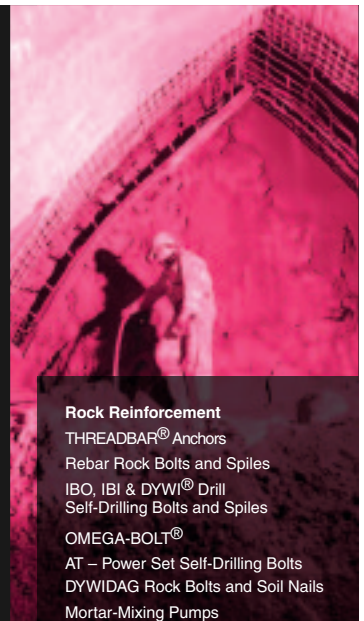
When micro-tunnelling gets underway, Denys hopes to achieve progress of 6m per shift. ▀

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Against limit state design in rock

It is inappropriate, if not meaningless, to attempt to apply limit state design methods, such as those encapsulated in Eurocode 7, to the design of primary support for tunnels in rock, particularly weak rock or any rock under high stress. By reference to some 41 case histories of major tunnel failures, this article shows that more than 85 per cent were the result of unexpected geology or hydrogeology. It is submitted that the unknowns and uncertainties in geology and hydrology cannot be properly dealt with by applying codified factors to geotechnical parameters. It is concluded that working stress methods should be retained for tunnel support design, and that such design would benefit, far more, from competent geological and hydrogeological understanding, than from faith in code factors.

Below: Hangzhou metro pit collapse, 2008



Dr Philip J N Pells, Adjunct Professor at the University of New South Wales and director of Pells Consulting, argues against the usefulness of limit state design in underground construction through rock

Introduction

Limit state design came from structural engineering where structure, loads, deformations and collapse modes are reasonably easy to know, or postulate, and can be appropriately factored. The factors in structural engineering are linked, closely to failure probability because material properties, and loadings can be defined statistically.

There have been great difficulties in defining limit stage design for geotechnical works, and in particular for works where there is substantial interaction between man-made structure and the ground (ref 1 and 2). Since the mid-1980s, Limit State

Codes have been developed in many countries for two kinds of geotechnical works, namely piles (AS 2159) and retaining structures (AS 4678 and BS 8002). These codes are quite complex, even for these simple types of works where each unit in the ground usually has only a few variables, namely:

- Undrained conditions: unit weight, undrained shear strength and stiffness.
- Effective stress conditions: unit weight, effective stress cohesion and friction, drained stiffness.

The publication of Eurocode 7 for Geotechnical Design (and BS EM 1997-1) has changed the landscape dramatically. Now there is bureaucratic pressure on the geotechnical profession to do all design using limit state methodology.

However, design of primary support for tunnels in weak rock, or any rock under high stress, is substantially more complex than designing piles or retaining walls. In this application, limit state design is inappropriate, and counterproductive.

This is not to say that limit state methodology is inappropriate in all tunnel support design. It probably could be used for segment design in soft ground tunnels, but whether it would add any value to present design procedures is questionable.

Learning from others

In 1981, when he viewed what became Eurocode 7, approaching over the horizon, M D Bolton (ref 1), then a lecturer at Cambridge, produced an erudite article, in which he wrote:

“We are therefore entering a critical period in which a concerted input of effort will be required in order to avoid pivotal philosophical mistakes which could so

constrain designers as to affect the degree of security of soil constructions in Europe for many years.”

He made, and justified, some very wise suggestions for the way forward, all of which seem to have been ignored. He also noted that, “Deterministic calculations based on observable mechanisms offer a more reliable route to decision-making in geotechnical design than do the processes of statistic inference,” and, “The omission of a limit state mode will not be rectified by application of larger factors against those limit-modes that have been recognised.”

Along similar lines Day, Wong and Poulos (ref 2) note:

“For a probability calculation to work there is an assumption that the actions and resistances are independent variables, i.e. that changes to the loading do not influence the resistance and visa versa... in the design of soil retaining structures this is not true because the same soil acts as a load and a resistance.”

A lecture by Dr Colin Smith of the University of Sheffield (ref 3) seeks to explain how limit state design, according to Eurocode 7, can be implemented for the two simple problems of bearing capacity of a pad footing, and a cantilever retaining wall. The process is not simple, or intuitive.

Smith points out two important points that are relevant to this article, namely:

1. For Ultimate Limit State (ULS) analyses, Eurocode 7 requires five separate checks:
 - EQU: loss of equilibrium
 - STR: failure of the structure
 - GEO: failure of the ground
 - UPL: failure by uplift
 - HYD: hydraulic heave, and
2. The Eurocode 7 factors address Ultimate Limit State only, and the code states (2.4.8(4)): “it may be verified that a sufficiently low fraction of the ground strength is mobilised to keep deformations within the required serviceability limits, provided this simplified approach is restricted to design situations where:
 - A value of the deformation is not required to check the Serviceability Limit State (SLS).
 - Established comparable experience exists with similar ground, structures and application method.”

Smith suggests that only STR and GEO are required for ULS for design of footings and retaining walls, SLS is left for a separate,



Above: The Nicoll Highway collapse of 2004

undefined, calculation.

However, tunnel support design must require consideration of EQU, STR, GEO, UPL and HYD, and is anyway usually dictated by allowable movements, namely SLS! Welcome to the world of acronyms and valid logic, but in this author’s opinion, impossible application.

The substantial difficulties associated with limit state design in geotechnical engineering are described clearly by Day (ref 4) who concludes:

“The following important points must be understood when using ‘limit state’ code methods.

- The partial factor method was adopted by structural design codes as a convenient way to carry out routine design based on probabilistic considerations. It produces a more consistent probability of failure than the working stress method.
- The ultimate load is a mathematical concept. It has no physical meaning.
- In geotechnical codes the partial factors are not based on reliability analysis as they are in structural codes.
- For geotechnical design, the partial factor limit state design codes are simply the old traditional design methods, but with the

factor of safety applied in a different way.”

In passing, Day notes the following dilemma when applying ultimate limit state (ULS) concept to retaining wall design.

“The earth pressure and pore water pressure are interrelated through equilibrium and the laws of physics. Partial factor limit state calculations apply factors to the soil pressure and the water pressures independently to determine the ultimate load. This ultimate load does not represent the true load at the limit state and has no physical meaning. It violates equilibrium and the theories that were used to determine the loads in the first place.”

It may be thought that all is well in structural engineering, at least where there is not structural-ground interaction. The article by Alasdair Beal (ref 5), in the June 2010 issue of *New Civil Engineer*, will rapidly dispel this false view. It is almost a horror story, and I offer the following extracts as examples:

(i) Language and symbols

The most surprising aspect is that Eurocodes also attempt to create a new technical language for engineering. All over the world, English-language

Table 1: Summary of Major Tunnel Failures 1964-2010

Case	Location	Date	Lessons Learnt
1	London	1964	Unexpected geology
2	London	1965	Unexpected geology, insufficient face support
3	Southend-on-Sea	1966	Unexpected old well
4	Orange-Fish, Sth Africa	1970	Unexpected dykes, gas, open joints and water inflows
5	Munich	1980	Local variation in geology
6	MART, Hong Kong	1983	Misinterpretation of geology
7	Romania	1985	Unexpected geology
8	Istanbul	1989	Unexpected soft clay
9	Seoul	1991(1)	Unexpected geology and hydrogeology, insufficient face support
10	Seoul	1991(2)	Unexpected weathered granite
11	Seoul	1992	As for Seoul 1991(1)
12	Seoul	1993(1)	As for Seoul 1991(1)
13	Seoul	1993(2)	As for Seoul 1991(1)
14	Austria	1993-5	Extreme groundwater flows and pressures
15	Heathrow Express	1994	Poor management, workmanship and quality control
16	Munich	1994	Unexpected geology
17	Los Angeles	1995	Unexpected geology, removal of existing lining
18	Docklands, UK	1998	Design error, EPBM blowout
19	Athens	1991-98	TBM not matched to complex geology
20	Hull	1999	Water and sand ingress during construction
21	Taegu, Sth Korea	2000	Unexpected geology and hydrogeology
22	Channel Tunnel Rail Link	2003	Collapse of unexpected old wells
23	Meteor Metro, France	2003	Not stated
24	Shanghai	2003	Failure of ground freezing
25	Hsuehshan, Taiwan	1991-2004	Unexpected geology and hydrogeology
26	SMART, Malaysia	2003-2006	Unexpected karst geology
27	Cross City Motorway Tunnel, Sydney	2004	Fatality from rockburst at about 35m depth
28	Kaohsiung, Taiwan	2005	Hydrogeology and construction error
29	Barcelona Metro	2005	Adverse geology and hydrogeology
30	Lane Cove, Sydney	2005	Failure to design for the unexpected geology
31	Lausanne	2005	Unexpected geology and hydrogeology
32	Barcelona	2005	Unexpected fault
33	Kowloon, Hong Kong	2006	Construction error with slurry TBM
34	MK1 Transfer Cavern, Chuquicamata, Chile	2007	Failure of rockbolt, shotcrete support system
35	Railway Tunnel, Inner Mongolia, China	2007	Unexpected groundwater
36	Kowloon, Hong Kong	2007	Construction error, compressed air
37	Sao Paulo	2007	Failed to account for geology
38	Circle Line, Singapore	2008	Loose ground
39	Subway Tunnel, Hangzhou, China	2008	Unexpected geology and groundwater
40	Subway Tunnel, Cologne, Germany	2009	Unexpected geology
41	Blanka Tunnel, Prague	2010	Three collapses, first two in 2008. Unexpected geology and groundwater.

engineering textbooks and codes have been written for over a century in standard technical English, using the familiar terms ‘stress’, ‘strain’, ‘load’, ‘compression’, ‘tension’, ‘force’,

‘moment’, ‘shear’, ‘torsion’, and ‘imposed deformation’.

However, Eurocodes set out to replace this with a new language based on the word ‘action’, which is given a new

meaning of ‘load or imposed deformation’. In this new language, loads become ‘direct actions’, imposed deformations are ‘indirect actions’ and axial forces, shear forces and moments become ‘action effects’, which may be ‘transverse’, ‘tangential’ and so on. Dead load becomes a ‘permanent direct action’ and imposed loads are ‘variable direction actions’.”

(ii) Calculations

“Eurocode load combinations involve considering each imposed load in turn as a ‘leading variable action’, while other imposed loads and deformations are applied as reduced ‘accompanying variable actions’. All the different possible permutations of factors must then be considered to find which has the worst effect.

For those who enjoy calculations and working with numbers, there is certainly fun to be had. However, before the governing equation can be applied the engineer must identify which variable actions can be considered as being separate actions in the calculation and which cannot, so as to apply the factors correctly. This also affects safety and economy, because if the total imposed load can be divided into separate actions, this reduces the design load and the structure’s safety factor. The more the loading on the structure can be divided up into separate actions, the lower the safety factor becomes.”

(iii) Geotechnical design

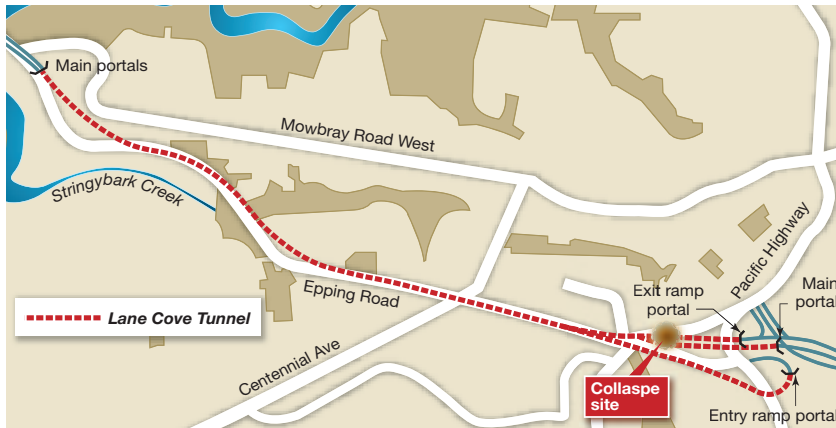
“Eurocode 7 part 1 for geotechnical design is the most radical and different of all Eurocodes. It proposes a complete change from past practice, with a new, complex system of partial factors replacing the traditional global safety factors of geotechnical design. According to Bond (ref 6):

‘When I last counted, there were 112 partial factors to choose from in EN 1997-1, with a further 34 converted from characteristic values to design values by the application of specific factors’.

Eurocode 7 changes almost everything that is said about geotechnical design in existing soil mechanics books and codes of practice, yet if engineers are to design structures to Eurocodes, they will have to master it.”

The show-stopper: problems in tunnel support design

Following from the above discussion, it is concluded that there are three reasons



Above: The corner of the residential building directly over the collapse;
Left: Plan diagram of the Lane Cove tunnel project with the collapse site shown

why limit state design of primary support for caverns in rock, particularly weak rock or any rock under high stress, is much more complex than design of piles or retaining walls.

1. There is no separation between 'structure' and 'ground'; overall behaviour is one of interaction, with the support elements affecting loading from the ground and groundwater, and the ground and groundwater affecting the support elements.
2. The engineering behaviour of just a single Geotechnical Unit, is a function of many variables, namely:
 - Unit weight.
 - Substance stiffness.
 - Substance strength.
 - Number of defect sets.
 - Spacing and continuity of defects.
 - Dip and dip direction of each set of defects.
 - Normal and shear stiffness of each defect set.
 - Peak cohesion and friction of each set of defects.
 - Water pressures.

Frequently, there are at least three defect sets (bedding, joints and shears) so the above list amounts to 38 variables. Some of these variables have to be increased to increase load on the support system, some have to be reduced to increase load.

Then there may be two to six Geotechnical Units, giving 76 to 228 variables, each which has to be factored, somehow.

3. Ground reinforcements, such as untensioned fully grouted bolts or cables, are neither 'structure' nor 'ground', but serve to modify the ground behaviour.

Given the above, it is no wonder that there is no specific Limit Design Code for design of primary support for caverns in rock. However, Eurocode 7 is a 'catch-all' code, and there are major tunnelling projects in Australia, and, no doubt, elsewhere in the World, currently under design, ostensibly, according to this code. The writer has examined the procedures set out in the design manual for one such project, and concludes that the methodology is non-sensical.

As a small example; following to Eurocode 7, the dead load is supposedly factored up by 1.35 by increasing the unit weight of the rock. However, as any trained rock mechanics engineer knows, the load on tunnel support is a function of the horizontal stresses as much as the overburden stresses; and also the relative stiffness of the rock mass and the support; and also the sequence of support installation as the face advances. Factoring the unit weight by 1.35 does not factor the load by 1.35. And factoring the natural horizontal stress by 1.35 will, in some situations, lead to a lesser load on the support, not greater. Again, as any trained rock mechanics engineer knows, this will depend on whether, in the definitions of Lauffer (ref 7), we are dealing with 'loosening pressures', or 'true rock pressures'.

Then there is the issue pointed out by Wong, Day and Poulos (ref 2):

"The code requires that the design resistance is equal to the characteristic strength of the material multiplied by each of the factors in series. The problem with this approach is that basic statistics demonstrates that the probability of such a design value occurring is miniscule. For example, if a strength factor of 0.8 is meant to represent a 0.1 per cent (0.001) probability of a more adverse value

occurring, then if there are five independent strength factors of all equal to 0.8, the resultant strength factor is $0.85 = 0.3$, and the probability of occurrence (assuming all have an equal probability) is $0.0015 = 1 \times 10^{-15}$, which is an unrealistically occurrence (assuming all have an equal probability) is $0.0015 = 1 \times 10^{-15}$, which is an unrealistically low probability of occurrence for design, particularly remembering that the loads will also be factored up."

If we have between 76 and 228 variables, as discussed above, it is fairly obvious that we are likely to find ourselves in unknown territory in respect to the reasonableness of the probability of failure of our final design. Notwithstanding this difficulty, there is even more fundamental reason why limit state philosophy should not be applied to tunnel support design. This is geological uncertainty.

Table 1 summarises major tunnel failures, documented by the Civil Engineering and Development Department of Hong Kong (ref 8), and also taken from the writer's own experience. The failures occurred between 6

1964 and 2010, some with terrible loss of life, all with great financial pain. Of these 41 failures, 35 (85 per cent) are ascribed to unexpected geological or hydrogeological conditions, three to management coupled with design, and three to construction errors. All the failures occurred during construction.

Jacobs (ref 9) discusses five other significant tunnel failures. In only one case, the Wilson tunnel in Hawaii, can the failure be ascribed to flawed design. The other failures related to geology, to water and to gas in the ground.

Eurocode 7 protagonists may argue that because about 85 per cent of the major tunnel failures, documented in

Table 1, were caused by unexpected geology or hydrogeology, we should apply a factor to geology. But this is impossible. Firstly, how do you apply a factor to something of whose existence you are ignorant. Secondly, how does one apply sensible factors to all the parameters listed when it is not clear which changes are adverse. Thirdly, given that the fundamental intent of limit state design procedures, such as Eurocode 7, is to achieve a known low probability of failure, how do we know what factors to select when we have no way of knowing what is the likely failure probability of the final design.

Given the above facts, we have two choices.

We could, not unreasonably, adopt the view of Nassim Taleb (ref 10), that the geological and groundwater conditions that led to the failures in Table 1 are 'Black Swans' - unexpected, unpredictable, outliers, carrying extreme impact. With the



Above: The Pinheiros station cavern and shaft collapse in Sao Paulo in January 2007

'Black Swan' view we may as well shrug our shoulders and hope.

Or we take my view that it is blatantly obvious that our profession should be concentrating on the proper training of engineering geologists, namely geologists who properly understand rock mechanics, and we should rely on these people, and not be trying to apply meaningless factors to, often, guessed geotechnical parameters.

In the first drafts of this article I set out to document, what I thought was, a sensible path for using the principles of Eurocode 7 in the design of tunnel support. These were the procedures that I had documented to introduce into a major Australian project which was locked into Eurocode 7. They included consideration of 80 factors for the geotechnical parameters, not including the orientations of joints, faults and bedding, and ground water pressures.

However, when it came to this final article I had to cut that out. My reasons are threefold.

Firstly, the only way I could achieve something sensible out of Eurocode 7 was to reduce it to something it is not, namely a system of partial factors of safety.

Secondly, I was wrong in my assessment of the factors - the reason being as set out by Wong, Day and Poulos (2007), and quoted above. The combination of all the factors gave a ridiculously low probability, but a meaningless one, because the real issue was uncertainty in the structural geology.

Thirdly, I found myself being sucked into the very place that should be rejected. This is the place where engineers consider that geologists and

hydro geologists have limited value, and the laws of physics are insufficient, or too difficult. And so we produce bureaucratic procedures to hide behind, and to make ourselves more comfortable.

Parting comment

A quote, attributed to Brian Simpson, encapsulates the issue.

"An understanding of limit state design can be obtained by contrasting it with working state design:

- Working state design: Analyse the expected working state, then apply margins of safety.
- Limit state design: Analyse the unexpected states at which the structure has reached an unacceptable limit.
- Make sure the limit states are unrealistic (or at least unlikely)."

The issue is that selection of meaningful 'unexpected' and 'unrealistic' states is impossible, or meaningless. For design of tunnel support, which, in weak rock, or rock under high stress, is dominated by geological materials and geological structures, and with the loading of the support being a function of the mass stiffness of the ground and the stiffness of the support elements.

We should, in fact we must, retain working state design, based on the expected. The expected should be based on detailed site investigations interpreted by the best engineering geologists, of whom there are too few. Then we must properly use the Observational Method, by whatever name we chose to call it, even the New Australian Tunnelling Method! ▀

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In the mix on site

There are many considerations when deciding how to supply the concrete necessary for lining and support in most tunnelling projects. Not least of these are how to source large volumes of material on site, and to deliver it to the location of use. With usually restricted surface space, and often long transport distances, this is no easy task. Maurice Jones checks on some developments to make it easier

Larger tunnelling projects requiring substantial amounts of concrete, whether sprayed or cast in situ, will need their own batching plants on or near the surface working site. There have even been instances of batching underground, but the raw ingredients will still need delivery. The mixes may be required for sprayed concrete (primary or permanent) support, grouting. Even when most support lining is provided by pre-cast elements, there will still be a need for cement mixes to fill the annular gap, for concreting non-standard structures, and perhaps for injection grouting and a final lining. Whatever the requirement, the batching operations will need to be capable of producing the amounts required on time, and have the versatility for mix adjustment to suit, perhaps changing, requirements.

Compact plant

Even if the tunnelling project is fortunate enough to have plenty of room in the working site, a compact, modular batching

plant may still be preferable to reduce transport and erection requirements.

The use of NATM in the construction of the 11.7-mile (18.8km) Phase 1 of the GBP 3.31bn (USD 5.25bn) Dulles Corridor Metrorail Project in Washington DC involves the use of a special dense sprayed concrete mix including microsilica and steel fibres. Preparation of the mix necessitated a mixing plant with a small footprint, since limited space was available, for which a Liebherr Easymix 1.0 plant was used. This is containerised to include most of the components in one assembly: mixing system, aggregate bins, water tank and microprocessor-based control room. The mix weighing equipment and cement feed are transported separately. With a steel base to the container, no separate foundation construction is necessary, but the plant was enclosed for winter protection.

The main mixer is a standard 1m³ ring pan mixer, with 48kW drive, but with the addition of a rotary agitator to better

ensure a consistently high quality mix. The fine microsilica is stored in a special silo with its own screw discharge and weigher. Steel fibres are also added at this point using a vibration bowl and belt conveyor delivery to the mixer. Another additive is a retarder to ensure a 3-hour mix workability life before application.

The mix control is achieved with a Liebherr Litronic BCSII computerised system including a Litronic FMS-II moisture controller. The output of the plant is about 30m³/h (109m³/day) with a batch cycle time of two minutes; plenty for the project's requirements. The plant's pan mixer discharges onto a belt conveyor and thence into special low-profile truck mixers to go into the tunnel. Construction started in March 2009 and is scheduled to finish in 2013.

Another Liebherr Easymix 1.0 is being used by Vegas Tunnel Constructors (joint venture of Healy and Impregilo) for the Lap Take No. 3 Tunnel Project in Nevada, US for Las Vegas water supply. The plant again supplies fibre-reinforced sprayed concrete plus annular grout for the tunnel to be lined with precast liner rings, and standard concrete for foundations. The plant is configured to supply spraying concrete very quickly through 24 hours.

For England's A3 Hindhead Tunnel, contractor Balfour Beatty employed a Liebherr Mobile 90 batching plant to produce sprayed concrete mix for a composite-type support and waterproofing lining.

Grout and more

Team Mixing Technologies (TMT) of Canada tends to concentrate on plants to produce grout and backfill mixes, chiefly for the mining market, but has also supplied some

Left: The compact Liebherr Easymix 1.0 batching plant used to produce reinforced sprayed concrete for the Washington Dulles Corridor Metrorail Project, US, includes many components in one standard container





Left, top: Another Liebherr Easymix 1.0 is used at the Lake Mead No. 3 tap tunnel project by Vegas Tunnel Constructors. Here it occupies a small footprint (left centre) within the working shaft site;

Left, bottom: CIFA's latest heavy-duty truck mixer, the HD12+



The Wetbeton 120 model was also used by Hindustan Construction Company (HCC) in Bhutan for the Kurichu and Tala dams and the Tala headrace tunnel. Production was up to 100m³/h using aggregates up to 120mm in size, plus flaked ice and chilled water for concrete cooling in the dams.

Adler Technologies of France offers horizontal, semi-vertical or vertical concrete batching plants with capacities of 10-60m³/h. Storage capacities are included according to client specifications in the ranges of 40-700t for aggregates and 30-100t in silos. Adler uses various mixing technologies but has developed the vortex principle in mixers in which the cement mixture is suspended whilst aggregates are propelled upwards into it. This is claimed to reduce cycle time, optimise mix quality, and reduce cement consumption. Other types of mixing used are turbo, planetary and horizontal shaft. Dedicated automatic control systems for batching plants are available.

major tunnelling products such as the Brisbane Airport Link. The company's list of supplies includes materials handling systems, electrical and control systems, and dust control measures as well as the basic batching plants.

In western Venezuela, TMT supplied 60m³/h concrete batching plants for both ends of the 24km-long Estrada Lara irrigation tunnel. The tunnel is to supply water from the lush Yacambu valley to the desert area in the neighbouring Quibor valley. The plant products are both concrete for spraying and for cast lining. The plants feature 4-yd³ (3.1-m³) Voelier pan mixer and is plc controlled. TMT carried out all functions from design to commissioning and training. Other features of the plants include aggregate storage bins, three cement silos each with screw conveyors, weigh hopper, dust collection system, belt conveyors and controls.

For the Thies-John Holland joint venture on the Brisbane Airport Link TMT designed fabricated and equipped two, fully automated, 2-component grout plants of 23m³/h capacity for annular gap filling around the two Herrenknecht EPB TBMs over 15km of tunnelling at 12.45m diameter. As with other TMT grout plants, the system features the company's high-shear colloidal mill mixers for maximum grout strength with minimal 'bleed'. High-

pressure Elepon ETK peristaltic pumps are used to transfer grout and accelerator to holding tanks on the TBM back-up systems. TMT also undertook on-site training and service support.

CIFA's (part of the Zoomlion group) range of concrete batching and mixing plants include both dry and wet work. The wet line has both horizontal and vertical concrete plants, the latter suiting limited space availability. These include the Cifamix units, whilst Turbomix and Rotomix double horizontal shaft concrete mixers have outputs of batched concrete up to 4m³. The dry process range come in Compact, Personal and Dual models with outputs of 40-150m³/h. Aggregate storage capacities are up to 300m³.

Tunnel projects that have been supplied with batching plants by Sinem of Italy include the Mont Blanc Tunnel post-fire reconstruction, and the Kurichu Dam and Tala hydroelectric projects in Bhutan. The Sinem Wetbeton range is modular in design to reduce site erection and assembly times to no more than ten days, and without any welding.

For the Mont Blanc project Calcestruzzi of the Italcement Group used a single Wetbeton 120 plant for the supply of sprayed concrete and cast structural concrete. The work demanded concrete batching work 24h/day over 15 months.

Truck to place

If the tunnel project has a relatively low concrete requirement, due to its dimensions or self-standing support, then it is possible to meet all concrete requirements by mixer-truck 'ready mix' concrete, particularly if the site is within economic travelling distance of a commercial general batching plant. In tunnels of sufficiently large section the mixer-trucks may enter the tunnel itself to carry the concrete to the area required.

CIFA's latest truck mixer addition to a wide range is the HD 12+, which, on a 4-axle carrier with a capacity of over 45t, is designed for heavy-duty applications including payload capacity of over 12m³. It features a thick-section drum and blades, double rollers with sling bar for improved off-road support, and an anti-rebound device. The discharge chute and charging hopper have wear plates, and the chute is hydraulically driven from a manual pump with adjustable support. The discharge chute can optionally be shaped to a cone with a 200mm-diameter hose extension. An on-board water tank, pressurised if required, is another option. ▀

Portal to point of use

There is no operation in tunnelling where timing is as important as it is in concrete delivery, whether the material is for permanent cast in situ lining, sprayed concrete lining or grouting. Thus the means of delivery must be reliable and available, compact enough to work within tunnel section availability (including mucking out operations), and convenient to use at the point of delivery where space is also likely to be at a premium. Maurice Jones examines the various means of tunnel concrete transport

As mentioned in the previous article, highway legal truck mixers can be used to deliver concrete and grout mixes to near the point of use in a tunnel, providing the dimensions allow it. There are also more compact specialist vehicles, more suited to tunnel conditions, but of normally lower capacity. However, in most large tunnelling projects with long drives, rail transport is employed to deliver materials. The frequently large volumes of concrete employed, particularly for permanent cast in situ lining, require high capacity vehicles.

Rail cars

Rail transport specialist Muhlhauser (KHM) offers a wide range of rolling stock for concrete and ingredients transport including both standard and custom-made designs. Standard Muhlhauser concrete remixer cars, with longitudinal axis rotation, have electrohydrostatic drives and a range of capacities from one to 14m³. For greater requirements, up to five cars can be used in series together in a train, one feeding the next up until the discharge point. Recent applications have been for the Gotthard Tunnel (TAT consortium) and the Brenner Tunnel. Mortar containers (portable boxes

or cars) are made with internal auger mixers with electric, hydraulic or pneumatic drives. Recent applications have included the Finnetunnel, Denmark (17m³ mortar car), SMART project in Kuala Lumpur, Malaysia (20m³ mortar car), La Cabrera Project, Argentina (11m³ mortar box, and Barcelona Metro Line 9 (6m³ mortar box).

An alternative is the transport of dry mix ingredients using silo cars with discharge devices such as horizontal screw or belt conveyors, or gravity feed chutes. The latter can have manual or automatic actuation of closure flaps. Muhlhauser says that all components are oversized long operating periods and life.

Trackless

Dedicated trackless concrete transport vehicles from Normet Utimec range in capacity from 4.4 to 5.6m³. They are lower in height than highway truck mixers, but the different models have a range of features to suit the circumstances. The Utimec LF 600 Transmixer, for example, with a capacity of 4.4m³, has an available tractive effort of 190kN for steep inclines and rough ground. It also has smaller wheels for fast operation.

The Normet range also includes a transferable cassette system called

Multimec, one cassette of which is a concrete remixer. Such a system can be used for intermittent concrete transport needs, but is most often found in mining applications. For greater needs, dedicated concrete transporters such as Normet's Utimec Transmixers and agitators can be used. The larger Variomec MF 050 M concrete remixer is a part of another Normet interchangeable module system, but mounted on an articulated carrier. Other modules are available for rock hauling and an access boom man-lift.

Truck mixer delivery

Where the tunnel section is sufficiently large, and removed of major obstructions, to allow the highway-legal truck mixers, one still has to decide on how the concrete is to be transferred to the means of use. The same applies to specialist underground truck mixers and modules such as from the Normet and Muhlhauser ranges, including rail-mounted mixers in the latter.

In many cases, particularly in the case of sprayed concrete, the truck mixer chute can be simply sited over the reception hopper of the shotcreting equipment for direct use while keeping the mix agitated.

At the other extreme there may be no alternative to pumping the concrete for cast in situ placement, such as in order to 'hose' the concrete behind formwork shuttering, particularly at high levels.

Where they can be used, small belt conveyors offer a mid-way to concrete delivery. They are best suited to low level concrete delivery such as for invert lining, track beds and pavements. Limitations are that delivery has to be in a straight line and steep angles of delivery may result in material slump back. The mechanism is



Left: A Normet Utimec low profile truck mixer emerging from a tunnel on Washington's Dulles Metrorail Corridor project



Above: The largest of Dieci's range of compact truck mixers – the F7000 with a capacity of 5m³; **Right:** A concreting train on Malmo City Tunnel project carrying an electrically operated Putzmeister and mixer cars to lay a slab track system; **Below right:** The new Series 8 Model 1007/712 trailer concrete pump to be launched by CIFA in April

relatively simple, however, compared to concrete pumps.

The Liebherr range includes compact LTB belt conveyors that can be carried on top of truck mixers using folding belt heads. In the 4-model range, delivery radii vary from 11.5 to 16.2m. In all cases the output is around 70m³/h.

Pumped

The other major option for concrete transport in tunnels, particular through smaller sections, is pumping. Although perhaps not as versatile as wheeled transport to cover distance, pumping can also be used to go around angles quite easily, including placing concrete behind formwork, and at higher levels. Even so, pumping can reach substantial distances that can make its use feasible in many tunnels. For example Putzmeister claims a world distance record for concrete pumping of 2015m, achieved with a BSA 14000 HP-D pump on a site in France. A top pumping height of 532m using a pumping pressure of 18.5MPa (185bar) has also been achieved.

The Putzmeister range can be applied to most operations up to 220m³/h delivery and 40MPa (400bar) pressure. Finer (up to 32mm grain size) materials, such as grouts and shotcrete mixers, can be handled by small, high-pressure pumps with 'S-tube' technology. Grout mortar (grain sizes up to 8mm) can be pumped over particularly long distances using pumps with ball-valve technology, obtaining pressures up to 13MPa (130bar).

Although there are many suppliers of concrete pumps, including truck-mounted versions, there are few that offer the range of tunnelling specialist equipment presented by Putzmeister and CIFA. The main areas of difference are in boom reach and pipe articulation, but this is more a matter of placement covered in the next article. There are also special skid- and rail-mounted pumps such as Putzmeister's RCU-702 Rail Concrete Unit.

When transporting concrete mix over long distances or great differences in height, whether by gravity, pumping or pneumatic conveying, attention has to be



paid to the possibility of mix separation with a tendency to segregation of heavy aggregates from binding ingredients and water. In order to combat this pump design and operation can be coupled with the use of mix additives.

In cases of intermittent mix usage, some form of bunkering may be advantageous. Dedicated remixer cars and similar devices are their own bunkering. In pumping operations Putzmeister offers the Jumbo Trough JT5000, the basic design of which can be adapted to particular user needs. The standard design has several mixing spirals to homogenise the mix, thus helping to avoid segregation. Capacities range from 2 to 15m³.

CIFA's latest mobile pump is the Series 8 Models 1007/712 with outputs of up to 100 and 65m³/h with respective maximum concrete pressures of 72 and 115bar. The low-noise, Deutz diesel-driven, trailer-mounted unit is designed for heavy-duty conditions. The main pump unit is of axial piston type for variable for capacity and constant power. The 'S-shape' valve fitted is suitable for any type of concrete. Components compensate automatically according to wear. Optional radio remote control is available.

Trains & shunting

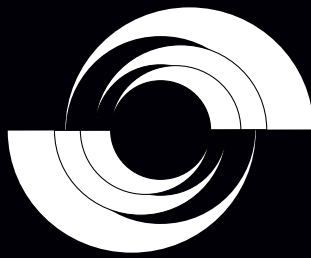
A recent appearance of an Adler Technologies tunnel concreting train was the new Gotthard base-tunnel just before the first main breakthrough in October last year. It started concreting the beds for the first metres of rail track in the southern portion whilst tunnelling continued further north. Work commenced after several weeks of 'real situation' testing and validation overall length of several hundred metres. The train comprises 23 cars



weighing a total of 1200t, and will be used to concrete the 57km of tunnel at a rate of 260m/day. Adler already supplied a similar train for the Channel Tunnel. Concrete batching train capacities range from 15 to 60m³/h for functions such as foundation bed and side structure placement and grout injection using on-board pumps or transfer cars.

An unusual means of moving concrete mix in tunnels is in the reported use of an ex-Swiss Army Mercedes Benz Unimog by contractor Marti in the Cassanawald Tunnel, Switzerland, last year. The Unimog can work on tracks due to road-rail attachments fitted by specialist company Zwiehoff by which it can negotiate grades up to three per cent.

The 40m-long train, weighing about 60t, included a 19m-long 'machine wagon' carrying both wet and dry-process concrete sprayers. The second wagon carried a permanent concrete mixer, the third compressors, and the fourth materials silos. Protection screens against concrete bounce-back are provided for the Unimog and the machine wagon. The equipment was used to apply layers of fireproofing mortar. ▀



Underground Construction

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29th and 30th June 2011



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Lining with security and efficiency

Second only to the 'excitement' of watching paint dry in frustration stakes, at least in tunnelling, is waiting for concrete to cure. Maurice Jones examines how formwork and concrete mixtures are increasing the efficiency of cast in situ concrete tunnel lining

Variable forming

Euroform, a company in the Herrenknecht group, has developed a new system of tunnel formwork or shuttering that is versatile for different tunnel dimensions. The EP Shutter has a modular design can therefore be used several times, and is easier to handle. According to managing director Allesandro Polla the easier handling allows faster assembly times and reduces transport costs compared to conventional shuttering. Euroform also claims a high buy-back value with only reassembly necessary rather than full refurbishment. The example of EP in the Euroform catalogue demonstrates the use of a hinged structure, anchors and struts, or other support frame, to cover a range of radii from 4.4 to 8.9m with the same components.

Euroform also supplies vibrating systems (for concrete settlement), reinforcement carriages and concrete distribution systems. Special formwork caters for vaults, inverts, niches, enlargements and circular sections.

Another variable arch form, supplied by Ceresola, has been used by the Thiess-John Holland contracting JV for large-width stretches of the Airport Link motorway. This is claimed to be the first time that an arch-form has been designed to line tunnels with multiple-lane configurations. Four sets have been used for concrete forming over 3-lane (17m wide) stretches of the road and a major cavern up to 30m wide on the Airport Link, and another in the associated Northern Busway tunnel. Thiess John Holland project director Gordon Ralph said that the relative speed of the variable-arch form is significant on this project as it is being completed within such tight time frames. Original assembly of a formwork set takes but reassembly between set-ups is not necessary. The recent flooding in Brisbane will, of course, have caused further scheduling problems. One arch



Above: A Putzmeister Telebelt is used for concrete placing on tunnels of the Xiluodu hydroelectric project on the Yangtze River in China

form can be used to line about 60m of tunnel a week.

Putting it there

Placing concrete where required in the tunnel can be a very tricky task especially when this has to be done at a high level, behind formwork and around any steel reinforcement used. These obstacles can usually be overcome with the use of concrete pumps of sufficient capacity, distributing pipework and accessories, vibrators, and appropriate concrete additives to improve flow and workability.

Another simpler and possibly cheaper approach in suitable circumstances is to use a belt conveyor. Putzmeister's Telebelt is a dedicated extending conveyor system that can be used to place concrete at substantial distance from the source, but generally at similar levels or in the invert. In addition to its major use on dam construction, Putzmeister Telebelt is being

used for tunnel concreting on the Xiluodu hydroelectric project in China, the third largest in the world. The first Telebelt TB 105 unit on site had already been seen on the Three Gorges Dam project further down the Yangtze River, accumulating 20 000 working hours. To more newer type 110G Telebelts were ordered for the SinoHydro Bureau 7. The concrete used carries aggregate particles up to 60mm in size, which would prevent the use of concrete pumps.

SinoHydro Bureau 7 is responsible for the overflow tunnel and surface structures, but the Telebelt also helps work by Hydro Bureau 6, Hydro Bureau 14 and others constructing the surge tank, underwater outlet and main transformer building.

Great attention has been paid to manoeuvrability in the design of the Telebelt, which is carried on a highway semi-trailer, which is versatile to meet local road weight restrictions. One Telebelt may be used at several construction sites on the

project. A tandem dolly is also available to move the semi-trailer with a dozer. Performance is also highly rated, with a Tebelb TB 110G emptying a 6m³ in 2.5 minutes at normal speed, or in 1.8 minutes at a higher speed.

Accelerated hardening

If concrete can be made sufficiently strong for removal of formwork at an earlier stage of the process then it follows that the quicker hardening, or curing, should produce an equivalent increase in productivity. This can be achieved by shortening the time that formwork or shuttering has to be kept in position in order for the concrete to cure, or reducing the number of sets of formwork required on a particular project.

The advantages of using accelerating and hardening additives in shotcrete mixes is now widely known, and is practically regarded as essential to achieve early support and maximise the efficiency of mix usage by reducing rebound (see below).

Now a development from BASF Construction Chemicals promises to allow

users to achieve substantial increases in the efficiency of concrete casting, both for precast products (see future October 2011 issue of *T&T*) and for cast in situ linings and other structures.

In addition to efficiency, BASF's new development also addresses the key requirements of a sustainable construction industry of energy demand reduction (lower carbon dioxide emissions), material optimisation, and meeting high quality specifications, chiefly by achieving high early strength development, whilst balancing the requirement for an optimum mix to achieve the concrete specification with the aims of using more binding material and reduced clinker content.

Crystal speed hardening

BASF's development is trade-named as 'Crystal Speed Hardening' (CSH) using the new 'X-Seed' hardening accelerator. The product is said to boost development of early strength in a way that was never achieved before by modifying the kinetics of cement hydration. Already primarily developed for precast production efficiency,

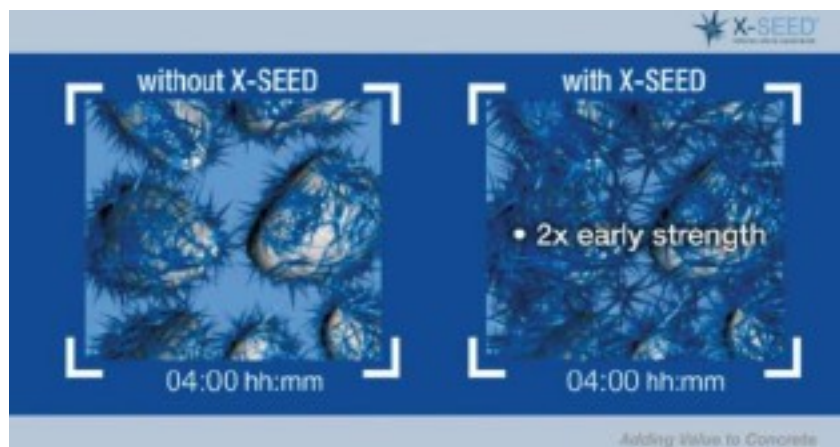
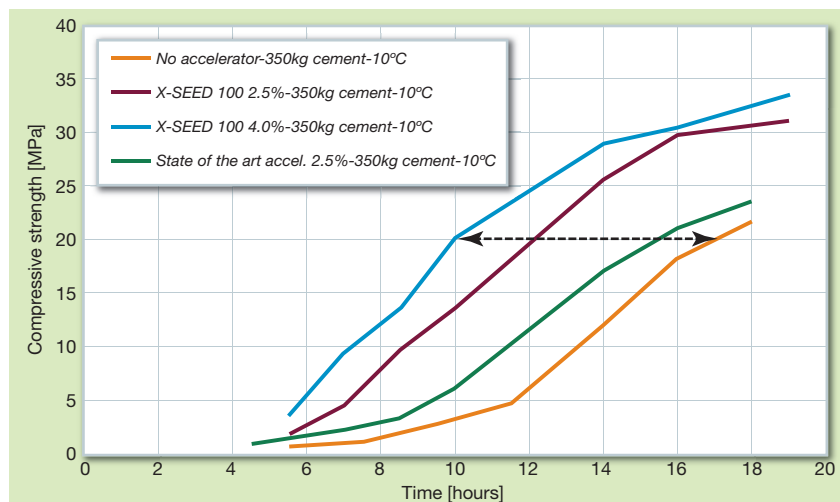
it also offers distinct advantages in cast in situ operations also. (See figure 1.)

The abbreviation 'CSH' also refers to calcium silicate hydrates; the products of cement hydration that are responsible for the compressive strength of concrete. The hydration speed depends on the chemical composition of clinker and other cementitious materials. In an induction period, in which there is nucleation and growth of hydrated cement crystals, there is slow dissolution of cement particles and formation of clusters, and their aggregation into small nuclei. This provides strength as the system is able to overcome an energy barrier allowing C-S-H growth to proceed.

Temperature increase can help accelerate strength development, albeit with some disadvantages, but this is impractical in most cast in situ circumstances.

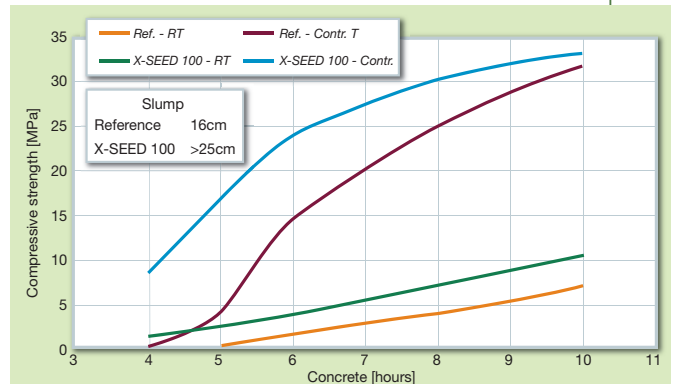
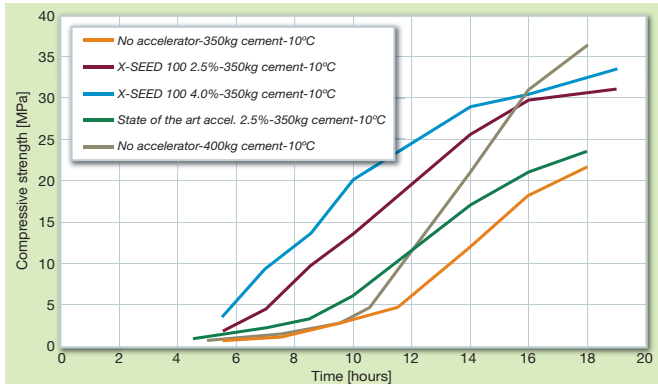
BASF's X-Seed 100 is a liquid suspension of crystal seeds containing synthetic nanoparticles designed to boost the hydration process of early-age cement (6-12h old), strongly accelerating the growth of calcium silicate hydrate crystals. It works at a wide range of temperatures, with crystals between cement grains growing quickly and promoting improved properties in the final microstructure through natural hardening, without the typical effect on durability of common accelerators, BASF claims. The crystals can grow with virtually any energy barrier as in standard conditions, with preferential growth in between the cement particles rather than layering on the particles as normal, thus slowing down growth. It is also claimed that surface layer can be of higher density, and slow down the diffusion of products and reactants. The accelerated formation of hydrates occurring in the presence of X-Seed is presented schematically in figure 2.

BASF has conducted three series of tests corresponding to different approaches to the use of the product, with concrete batches with different dosages of X-Seed 100 compared to plain concrete (with no accelerator) as well as concrete treated with traditional accelerator such as concentrated solutions of nitrates, thiocyanates and formates. Traditional accelerators, for comparison, were used in the dosages that have previously resulted in the best performance. Two different dosages of X-Seed 100, 2.5 and 4.0 per cent, were used in the tests. (See figure 3).



Left, top: Figure 1 – Development of an early compressive strength of 20N/mm² as shown by dotted arrow;

Left, bottom: Figure 2 – Schematic view of CSH crystals in cement and water pore solution



Above, left: Figure 3 - Development of compressive strength with various mix recipes with and without accelerators

Above, right: Figure 4 - Graph demonstrating a 20 per cent productivity increase, and better workability with X-Seed 100

The CSH concept, of which X-Seed is a key component, is compatible with all BASF admixture technologies such as the 'Zero Energy System' and 'Smart Dynamic Concrete', says BASF.

Spanish application

One application of X-Seed in the formation of a tunnel concrete lining is the UTE Legutiano Tunnel on the high-speed railway between Madrid, Bilbao and Donosti in the Basque Country, northern Spain. The concrete specification required a final strength of 80 MPa, with an early strength requirement of 12-15 MPa to reach 12 MPa as soon as possible (see figure 4).

X-Seed 100 additive has been used in a mix design of:

- CEM I 52.5R 520 kg/m³
- Sand 0-5 780 kg/m³
- Aggregate 5-10 150 kg/m³
- Water 155 kg/m³
- W/C 0.3 kg/m³
- Glenium TC1323 1.3 per cent
- Meycom 685 1.5 per cent

The results are shown in the graph of figure 4, demonstrating a 20 per cent increase in productivity and better workability.

Sprayed concrete

The advantages of spraying rather than casting concrete are widely appreciated, for permanent (secondary) as well as temporary lining, not least removing the need for formwork and the efficiencies that produces. However, just because sprayed concrete can be applied relatively easily, and can be adapted to site conditions, it does not mean that it can be applied without care and attention to specification. The SCL (sprayed concrete lining) design approach, and structured NATM, still demand careful attention to the efficacy of the mix and the means of application in

order to ensure proper coverage, and both short- and long-term properties.

One property that is usually vital to a successful sprayed concrete lining is early-age strength development, through the use of accelerators and other additives. In tunnel situations the accelerator, invariably now non-alkaline, (such as Sika Sigunit, Mapei's Mapequick, BASF Meyco SA series, Shotcrete Technologies' ST-Alkali Free) has to be added at the nozzle, or just before. Controlled dosing is necessary to achieve the right mix. Other additives, such as water reducers (e.g. Sika ViscoCrete-SC, BASF Meyco Delvocrete, Mapei Mapeplast) and retarders for extended workability and slump-life (e.g. Sika Tard, BASF Meyco Glenium, Mapei Mapetard) may be added to the mix earlier, to balance the effects of transport and storage procedures.

It may be that early-age strength development is more important in temporary/primary lining; especially to control possible ground movement. However it can have an important part to play in permanent support, even if it is not part of the overall lining specification. In the deep Sedrun section of the Gotthard Tunnel four Sika-Putzmeister 500 rigs, with a 17m reach, and two smaller Sika Aliva 500 concrete spraying systems were used to apply layers of steel-fibre reinforced sprayed concrete to achieve a final thickness of 150-290mm for primary lining. This was followed by a waterproofing layer and cast in situ concrete using formwork to produce permanent lining of 300-1200mm. The sprayed and cast concrete employed Sika additives such as superplasticisers to ensure long 'open' times and early age strength. On the Sedrun spray systems, an automatic plc is used to achieve synchronisation of additive dosing in co-ordination with the concrete pump.

Putzmeister has introduced a new Sika-PM4207 concrete spraying system to

replace the Sika-PM 407 model, but it is five units of the later that are being used on the Pahang-Selangor Raw Water Transfer project in Malaysia. Most of the 44.6km-long main tunnel is being driven by hard-rock gripper TBM in granite, but there is 8.5km of NATM main tunnelling (in metamorphic rock and portal zones, and four access adits totalling 2.5km in length. The non-TBM drives are all horseshoe shape in section with typical NATM-type support patterns including reinforced sprayed concrete to around 50mm thickness in NATM drives (rock class B), and 100mm in the adits (poorer rock class CII). The contractor, a joint venture of Shimizu, Nishimatsu, UEMB and IJM, is employing the five Sika-PM 407 concrete-spraying systems fed with material by highway-type truck mixers. Typical sections are 4.60m wide x 4.70m high in the NATM main tunnel stretches and 6.6m wide and 5.40m high in the adits. Work began on June 2009 for completion in May 2014.

The new model Sika-PM 4207 spraying rig is based on the 407, retaining its compact form and versatility despite the inclusion of new features, as requested by customers. The basic frame is designed to be very robust for tunnel work, and the carry customer-specified options. Special features of the 4207 include an additive management system to save material costs, computerised control interface and colour display showing performance data, mix composition, error diagnostics, warnings, a standard rops/fops cab, xenon working lights, protected support legs, and an optional turbocharger for use on diesel engines at high altitude. Various options include power cable drum, a catalytic converter and diesel particle filter, fire protection and a water pump. The Linthal 2015 hydroelectric refurbishment project in Switzerland, part of the Linth-Limmern network of power

stations, makes considerable use of advanced sprayed concrete equipment to line caverns and tunnels. The plant list includes four Meyco Potenza Robojets with contractor Marti, a Meyco Spraymobile and Suprema with Rothpletz, a Meyco Rama 6 spraying manipulator and Meyco GM dry-mix spraying unit used with a Herrenknecht hard-rock gripper TBM, and wet-process spraying equipment with the Aker Wirth TBM driving an access incline.

Two Potenza units provided immediate support of the control cavern, and it was one of these machines that had to be carried by aerial cableway over several hundred metres to get to the work area. Another Potenza is being used to secure a drill-and-blast access drive, using Meyco SA 166 accelerator and Rheobuild T3 plasticiser in the concrete mix. BASF Construction Chemicals also supplies to local concrete batching plant with Glenium Ace 30 hyperplasticiser and MicroAir 302 air entraining agent for pre-cast segment production.

Environmental considerations in spraying concrete are not restricted to the dust suppression available in using wet-process application, which is, in any case, generally preferred for large volumes. The suitability of drives for an enclosed working environment is also important and has received more consideration. The latest in the CIFA application equipment is the CSS-3 step3 that now has a tier3-stage3 low-emission diesel drive with catalytic exhaust. Options include an anti-particulate filter, additive tank heating and fire suppression system. The carrier is a 4-wheel-drive vehicle for a maximum speed of 27km/h using hydrostatic transmission. Three steering modes available are 'normal', four steering wheels, and 'grab' steering. Concrete output is 5-30m³/h.

On the CSS-3 concrete placement is facilitated by a 3-section boom, including a 2.7-m telescopic section, with double-axis independent movement. The boom turret also has a 3.7-m slide on the longitudinal axis. The reach coverage is up to 16m radius. There are two drives for versatility – a 55kW electric motor and a 61kW diesel – with power take-off. The carrier has four stabilisers with a self-leveling sensor for real-time diagnostics. A remote control console can be used for a better view of the application area.

Control and instruction

The principles of controlling correct application of sprayed concrete are well known, and can be carried out by manual manipulation by well-trained operators. However, the operation is subject to human error and fatigue, even if access platforms



Above: A Meyco Potenza concrete spraying system was transported by a Garaventa cableway to excavations for the Linthal 2015 hydroelectric project refurbishment scheme

can get the operator into the position.

The advent of robotic spray nozzle manipulators has made it easier to control the best pattern of sprayed concrete application, and this has opened the door to fully automatic operation, later coupled with profile surveying systems, such as Amberg's TMS, to ensure the minimum thickness specified has been applied, and any voids filled.

Importance of training

It will be clear that adequate training in sprayed concrete application is important to maximise the chances of a satisfactory concrete lining, whether by manual, robotic or automatic nozzle operation. Several national bodies have developed specialised training and 'Nozzleman' certificate programmes, and some have combined in international programmes or exported knowledge to other countries.

Coupled with the recent availability of robotic, and even automatic (e.g. Meyco Logica) systems, simulators have been developed to aid in training and further develop operating procedures. Putzmeister has developed such a simulation system based on 'open-source' software, in co-operation with the Technical University (TU) of Dresden, Germany. The system was first demonstrated at last year's Bauma exhibition, based on the Sika-PM 500 robotic system. The software framework, Sartorius, cross-links subsystems of mobile machines in 'virtual' surroundings. It is provided by TU-Dresden who says that it provides improved methods for the development of more efficient, robust and flexible software systems for machine and

vehicle simulation.

The simulator was developed as part of the Inprovy research project carried out by the Chair of Construction Machines and Conveying Technology of TU Dresden co-operating with various construction machinery manufacturers and supported by the German Federal Ministry of Education & Research. The systems can be used for both product development and, with adaptation, training in a virtual environment.

In operation, signals from the original control unit of the Sika-PM500 are converted into CAN-Bus signals that can be interpreted by the simulation software. The user controls the simulation model, including the flow of concrete, and the results are transmitted to the visualisation model of the tunnel, applicator and spraying concrete. According to Timo Penndorf, computation and simulation specialist with Putzmeister, the distinctive feature of the simulation models is that they consist of systems of differential equations calculated in real time. Penndorf says this improves the 'degree of realness' considerably, for example as far as the 'after-bounce' of the spraying unit is concerned. ▀

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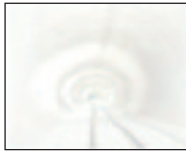
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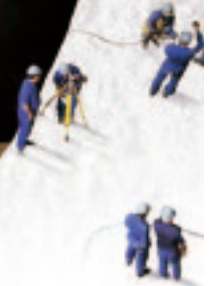
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Metro ventilation

Paul C Miclea, director of Aecom Global Tunnel Ventilation Services, Oakland, California, discusses the ventilation demands on modern metro station design and the essential considerations of space for ventilation facilities for both normal running and emergency requirements



Above: Modern fan room with axial fans (300m³/s in total) and sound attenuators (Photo: Dr Sean Siew)

Since 2008 most of the world population lives in urban areas. There are more than 300 cities in the world with a population of over one million and all of them require efficient, safe means of transportation. It is estimated that metropolitan railways transport more than three billion passengers yearly, 12 million per day¹.

New transportation systems often require routes along the most densely built city arteries so limited space for the required right of way and for new stations constitutes a major demand for designers, requiring elaborate trade-off studies of what can and cannot be done.

Transit organisations must provide reasonable levels of life safety to passengers, operating staff, and others. Modern mass transit systems with underground stations require entrances from the street level, as well as shafts blended within the existing city architecture. The stations should be inviting for riders and enhance the city environment as gateways to the communities.

Dedicated structures and spaces needed for tunnel and station ventilation represent an important part of the total envelope and of the cost of an underground station^{2,3}. For this reason it is imperative to integrate the ventilation system and structures into the station design, to ensure safety and security functions.

State-of-the art design of fire-life safety systems and security features must

facilitate air circulation and smoke control in case of an underground fire. Provision of emergency exits for the expected (maximum) occupancy that can be protected from smoke in case of fire should be incorporated in the design.

Transit stations are normally designed with fan shafts and fan plants attached to the station (at the end of the platform, with the shafts 10-20m inside the tunnel). The shafts are designed to operate as blast/relief vents during normal operation (to alleviate the pressure of the incoming trains) or as fan shafts, by closing the dampers on the relief section of the shaft. In some cases, where the distance between stations is long, reducing the efficiency of station fans in case of an emergency in the middle of the tunnel, mid-tunnel fans are also provided. This scheme presents significant advantages compared with the others but at higher cost. For new subway systems or extensions to existing systems, the additional cost for the inclusion of such dedicated emergency ventilation systems can be justified^{4,5}.

Station function & design

Approach

New systems should be designed with sufficient flexibility for growing capacity and capable to absorb risk factors brought by reaching maximum utilisation, including the changes in operating modes and threats associated with unexpected crowds and

behavior. The design should consider passenger flow in normal and emergency conditions, based upon patronage calculations and evacuation requirements, particularly in case of a fire.

Adequate space for electrical and mechanical equipment, station and emergency ventilation equipment and numerous other components should be considered from the conceptual design onwards. Such equipment in an underground station requires large amounts of very valuable space. These systems are necessary to maintain the operations of both trains and stations. They also support the safety of the passengers and provide protection during emergency situations. All these systems necessary to insure the quick and safe evacuation of the station should be given the highest priority.

Suitable evacuation routes and spaces through the station must be provided including sufficient space in front of the stairs and escalators. The width of the stairs and escalators should consider not only accommodate the maximum number of people, but also the maximum air velocity during an evacuation.

The large air distribution fans at both ends of the station are designed to operate during a fire emergency to remove smoke

from a fire, allowing passengers to evacuate the area. These fans are also designed to pull smoke away from the exiting patrons and carry it through ducts and shafts out of the station, up to the surface and prevent recirculation through entrances. This station fans capability is paramount in emergencies, given the fact that in case of a train fire in the tunnel, most operators require that driver should not stop the train, but continue to the next station for evacuation and fire fighting.

Interactions

A metro system should, as far as is possible, be designed to take advantage of natural ventilation caused by the train operation, since air generally moves in the direction of train travel. The positive pressure in front of a train moves air through tunnels and station entrances; the negative pressure behind the train induces airflow through similar openings. Considerable short-circuiting of air flows occurs in subway structures when two trains traveling in opposite directions pass each other. Such short-circuiting might occur in both station and tunnels with nonporous walls through cross-passageways or other unrestricted airways. To reduce these negative effects, ventilation shafts are customarily placed in the tunnels, preferably just outside the station ends. During normal operation these shafts in the approach tunnel operate for pressure relief ('blast shafts'). Thus the structures work as 'relief shafts' in the departure tunnel, relieving the negative pressure created during the departure of the train and inducing an intake of outside air through the shaft. The direct effect of this is a reduced airflow is a more comfortable environment for passengers.

The emergency fans and their connecting ducts require large spaces either within or adjacent to the station envelope.

Station costs

Due to the high cost of underground excavation and construction, the size of the station must be kept to a minimum, without sacrificing the overall functions and especially the life safety requirements. There are considerable differences in capital costs from country to country, often from region to region and, therefore, it is difficult to provide specific costs. Station appendages, such as fan rooms, impact the right-of-way and consequently represent a major cost item as well.

Station costs tend to be generally several times higher than tunnel costs per unit of length, due to the added space for platforms, as well as to the auxiliary space

for fan rooms and ducts.

Emergency fan rooms require space for fans and their appurtenances (transitions, sound attenuators, ducts, control panels, etc). Usually the axial, reversible fans are installed horizontally, often in parallel, with sufficient space around for maintenance. There are cases, particularly for deep stations, when the fans can be installed vertically, in shafts, thus reducing the space in the stations.

Ventilation system design

There are relatively few regulations and criteria for rail tunnel ventilation. The main document that provides guidance and general recommendations for subway ventilation and environmental control is the Subway Environmental Design Handbook⁶. Many of the subway transit systems in existence today have been designed and built with ventilation features adequate for normal train operation at the time, not always considering emergency conditions.

Current design concepts

Current concepts of sustainable design for tunnel ventilation systems consider the worst-case scenarios that might happen during all operational conditions: normal, congestion and fire emergencies⁷. There is a clear distinction between the requirements for passengers' comfort during normal train operation, as compared with what needs to be done to maintain safe operation in case of traffic congestion in the tunnel, or when an accidental fire happens in a tunnel or station. In most cases the required level of safety is achieved by the natural ventilation created by moving trains that usually ensures air velocities in enclosed stations and trainways greater than 0.75 m/s required by the current safety standard.

The US National Fire Protection Association's (NFPA) Standard for Fixed Guideway Transit and Passenger Rail Systems known as NFPA 1308 as well as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Handbook - HVAC Applications, Chapter 13 - Enclosed Vehicular Facilities (2007)⁹ and the Air Movement and Control Association (AMCA), provide specific design and operation requirements for metro ventilation systems. Some of the existing, old metros are upgrading their ventilation systems to comply with the new safety regulations^{10,11}.

These general design criteria are often supplemented by specific requirements and practice demonstrated by experience in a certain industry or jurisdiction. Project specific design criteria are generally

prepared by the owner's consultant, in coordination with the authority having jurisdiction (AHJ), as an expansion of the DOT, NFPA, ASHRAE and AMCA standards.

The environment in a metro station during normal operation should provide a smooth transition between outside conditions and those in the transit vehicles. ASHRAE and the SEDH (Subway Environment Design Handbook) recommend that a minimum amount of outside air should be introduced into tunnels and stations to dilute gaseous contaminants. There are no limitations for maximum airflow but air velocities in public areas should be limited to avoid nuisance.

For emergency conditions the ventilation system must be capable of clearing smoke and hot gases and maintaining a safe evacuation path to a point of safety, while allowing fire-fighting operations. The minimum air velocity in the affected tunnel section should be sufficient to prevent the smoke from 'backlayering', but the maximum air velocity in the evacuation routes should not exceed 11 m/s.

The ventilation system is sized for the worst emergency condition, which, most of the time, is for a major fire; therefore, often the terminology refers to it as the emergency ventilation system (EVS)^{12,13}. In case of a tunnel fire the operation of the EVS must be activated to ensure a safe evacuation of passengers and to maintain tenable conditions along the evacuation route for the required evacuation time.

When stations are designed with an EVS, the fan shafts can be located either inside the underground station's envelope, or outside, at grade, attached to tunnels. Fan shafts are usually 10-20m away from the platform's end. As mentioned above, mid-tunnel fan shafts may be necessary. While there are advantages and disadvantages associated with either system, in most cases the driving factor is the capital cost (usually lower for end-of-station shafts).

Given the diversity of station design, it would be difficult to even attempt a recommendation for the best emergency ventilation method. One simple principle should be implemented, however: in case of a major vehicle fire in the station, the smoke and heat should be controlled in such a way that at least one safe evacuation route is maintained. The design should incorporate means and procedures to prevent smoke migration in the mezzanine or other public areas other than the platform where fire originated or close to the fire tunnel section.

The ability of a particular ventilation system design to provide adequate ventilation during normal and emergency



Above: Large axial reversible fan

conditions can be evaluated using computer modeling and simulation techniques. A train fire will cause a sudden change in the tunnel ventilation pattern by adding an unsteady and fast-growing source of heat. The hot air and gasses created by a fire will tend to flow uphill, possibly against the normal flow, producing 'backlayering'. To prevent this enough ventilation must be provided and the criterion to establish the required airflow is called 'critical velocity'. Several computer software packages are available for special applications on tunnel and station ventilation as well as to model the spread of smoke and heat in case of a major tunnel fire, using computational fluid dynamics (CFD) techniques.

One requirement for the EVS to be considered in the station design and shaft location is the need for regular testing of emergency fans (noise considerations) and evacuation exercises that often may affect the neighborhood. Where available, parks, squares, vegetation landscape are preferred locations on surface for ventilation shafts and their housing.

The design of the ventilation shafts should consider other factors, including the sectional area and shape sufficient for the maximum airflow expected, smooth lining to minimise air friction, a raised shaft head on the surface to minimise impact on environment, and reasonable distance from station entrances or buildings (to prevent air recirculation and pollution of nearby facilities).

Smoke and heat control

Fires in tunnels and underground stations may be caused by accidents, electrical faults, sabotage or vandalism. Priorities following a fire are rescuing people and saving lives, extinguishing the fire, preserving the structure, investigating the cause, and then undertaking modifications or implementing procedures to prevent a recurrence. Burning fuel, oil, plastics, and some paints cause dense smoke and toxic fumes that hamper visibility and can produce death by asphyxiation. Temperatures may reach more than 1000°C, causing severe structural damages.

Emergency ventilation and evacuation procedures are important because the smoke and other fire products have a tendency to move upwards out of the stations and contaminate normal passenger exit routes. The EVS must be able to support evacuation by providing reliable, well-defined routes out of the tunnel corresponding to the emergency airflow patterns.

To facilitate safe and orderly evacuation of patrons from the station, signage, graphics, exit lights, a public address system and other components are streamlined into the design process. The design of the EVS, local mechanical ventilation and fire-life safety systems in the facility are to be performed in co-ordination.

Specific ventilation requirements

The environment in a metro station should provide a smooth transition between outside conditions, those on the platform and in the transit vehicles.

There is inconsistency in the way various transit agencies design and build the stations and shaft houses. There are stations without any mechanical ventilation (except natural ventilation), stations with a ventilation system to control the environment under normal conditions only, stations with an emergency ventilation system and stations with more than one system.

The California Building Code contains specific requirements for separation of shafts and other openings to prevent smoke recirculation, restricting the termination of shafts at grade or on roadways. The code does not contain specific requirements or recommendations for the height of the shaft house¹⁴.

For normal conditions a minimum 0.0035m³/s outside air per person is recommended to dilute gaseous contaminants, and maximum air velocities in public areas should not exceed 5m/s. For passengers' comfort the platform air temperature should not exceed the ambient temperature by more than 5°C.

Equipment & structures

As stated earlier, in case of a vehicle fire in a tunnel, the EVS must be able to ventilate

the maximum fire at each and every possible location to support evacuation by maintaining the routes clear of smoke and heat. Visibility influences the evacuation speed, critical in saving lives.

The NFPA 130 standard, as well as some of the US state building codes, specify that during an emergency all the occupants of the station boarding platform must be able to evacuate the platform within four minutes and that all occupants of the platform/station must be able to exit the station within six minutes. This requirement has a significant impact on the design of stations.

To achieve the required safety functions, the EVS must have a capacity to meet the demands of a worst-case scenario, ie for the maximum fire size and the largest population to be evacuated. Properly designed emergency fan plants (figure 3) play the main role in providing for a safe evacuation route and for protecting the infrastructure of the transit system. A typical fan room size for two axial, fully reversible fans of 120m³/s (250 000ft³/min approx) each would be 14m long, 14m wide and 5.8m high (46ft L x 46ft W x 19ft H), with a 2.4-m (8ft-wide) equipment door between fans. The room size is based on 4.3m x 4.3m x 2.15m (14ft W x 14ft H x 7ft L) sound attenuators at both ends. In addition, an electrical room of 7m x 3m x 3m (22ft L x 10ft W x 10ft H) for the fan damper control panel and two starters is usually required. Other auxiliaries include an emergency management panel room, near the station entrance and a substation room.

Integration with station design

The station fire-life safety system also contains smoke and heat detection and public address systems with pre-recorded announcements, as well as closed-circuit TV monitoring. All the critical equipment and lighting in the station is designed to run on an emergency power source, if normal power fails for any reasons.

In some cases, particularly for multi-level stations, a separate smoke exhaust system is provided for station emergencies. This system generally caters for small on the platform level. They cannot, however, control the heat and smoke generated by a large vehicle fire, for which large tunnel emergency fans are recommended.

Sprinklers are not considered for tunnels; where installed, there are serious concerns for activating the sprinkler systems during a major vehicle fire requiring evacuation, when the platforms become slippery and may impede on the evacuation time. To alleviate this risk, the protocol is to activate the sprinklers after



Above: Modern fan room with axial fans (300m³/s in total) and sound attenuators (Photo: Dr Sean Siew)

the evacuation is complete, which reduces the expected effect of controlling the temperature by cooling the fire. Standby pipes (either dry or wet) are normally installed and provided with fire-fighter hook-ups at pre-established locations¹⁵.

One important aspect of fire-life safety in tunnels and underground stations is the need to maintain power for the fans and lighting. NFPA 130 requires that emergency fans be powered by two separate, independent sources, in the event of a power outage. These sources may be electric power from two different substations, or an electric source from the main grid and a local generator.

As part of the overall fire-life safety and evacuation procedures, the tunnels and underground stations must be provided with detection, alarm, and annunciation systems, for emergency warnings and the capability to provide instructions to passengers¹⁶.

Traction power and other electrical systems utilise large amounts of ancillary spaces that must be ventilated to maintain operating temperatures. These spaces, usually large components of the entire system, have to be accessible from outside

the station to replace equipment quickly to maintain system operations. Given that substations normally require cooling of the equipment, their ventilation systems should be designed to discharge the heat to the ambient environment, rather than the tunnel.

Conclusions

Passengers expect the transit system they use to be inviting and safe, in case of accidents such as fires. Although there is significant progress in reducing the risk of fire, the risk and the cost of a major fire in tunnels or underground stations still exists.

Transit stations must provide not only quick passenger access to, or exit from the trains, but also comfort during normal operation and safe evacuation in emergency situations. Underground this becomes more critical, given space limitations and the costs involved, with the ventilation structures accounting for up to one third of the entire station volume.

Fire-life safety criteria, standards, regulations, guidelines, and recommendations vary widely, from country to country, sometimes even nationally. There is no single method to provide protection to passengers and to avoid material damages. However, a coordinated effort in the design of an integrated system that satisfies all safety requirements, as well as combining prevention techniques with the use of mechanical emergency ventilation, is becoming the norm.

The building codes and standards that govern the design of underground transit stations are very important due to the unusual environmental and logistical issues that are encountered in such facilities. The high cost of underground excavation and construction dictates that the size of stations must be minimised. ▀

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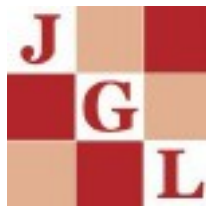
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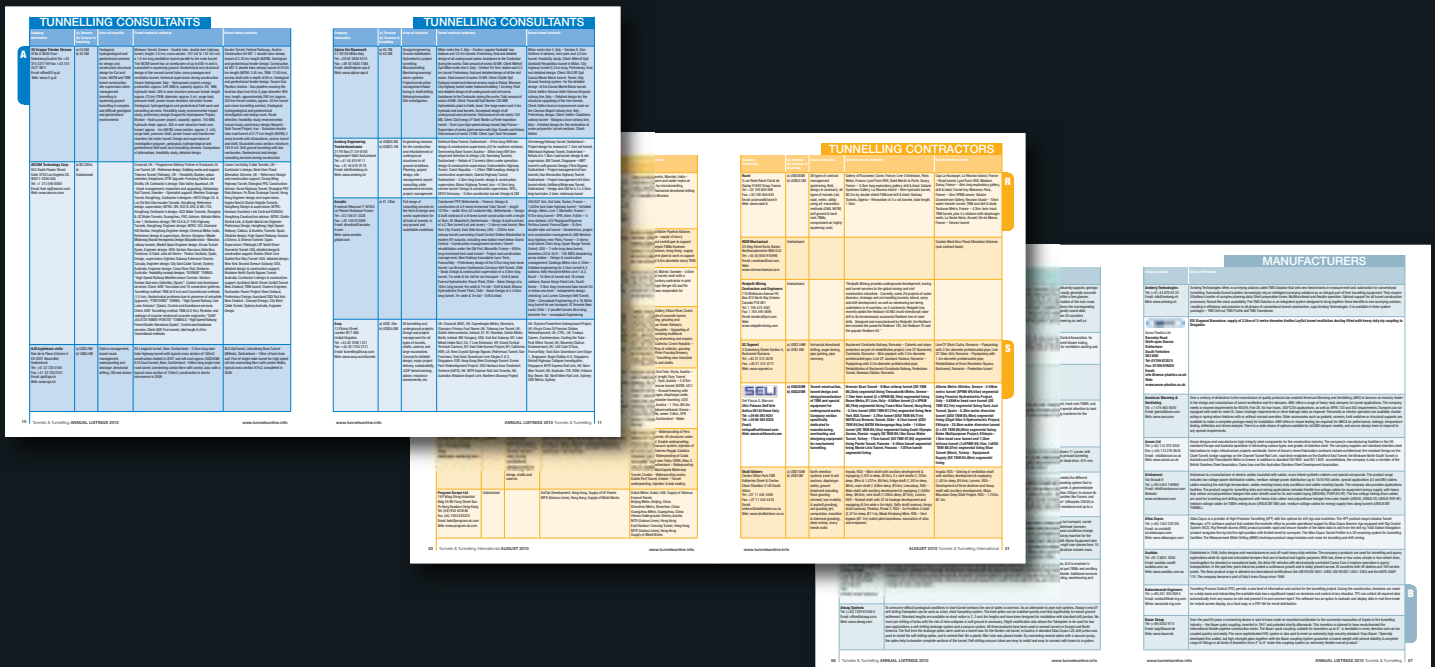


T&T's annual company listing and rankings have gone digital

All entries now need to be completed via the online entry form

Deadline for completion is 1 May 2011

The listings will be published with the August issue of T&T



Log on to
www.tunnelsandtunnelling.com
to complete the entry form

7 - 10 FEBRUARY 2011

Russian experience and development of innovative technologies for the construction of tunnel projects in Sochi

The purpose of this conference is to share Russian and international successful experiences in construction of transport tunnels, as well as to contribute to effective problem solving which occurred during the design and construction of tunnels in Sochi. Specialists of Russian design, engineering, construction and research organisations will participate in the conference.

Russian Tunnel Association:
Tel.: (495) 608-80-32, 608-81-72
Email: rus_tunnels@mtu-net.ru

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

8 - 10 MARCH 2011

The 14th Australasian Tunnelling Conference

Organisers are aiming for a meaningful conference to mark the start of the Second Decade of the 21st Century, setting a standard for the 2014 ITS Conference in Sydney. An extensive array of topics are to be covered. Contact: Belinda Martin, the AusIMM. Tel: +61 3 9658 6125
Email: bmartin@ausimm.com.au

13 - 16 MARCH, 2011

2nd Annual Tunnels & Underground Construction Summit, Abu Dhabi

Building on the success of the 1st Annual Tunnels & Underground Construction Middle East summit, which was held in May, in Abu Dhabi, IQPC is delighted to announce the dates for its 2nd annual event. Featuring:

- * A transport projects focus day
- * More case studies and scientific papers with over 25 leading speakers

- * More participation from Saudi Arabia, Qatar and Egypt

Tel: +971 4 364 2975
Email: enquiry@iqpc.ae

7 - 9 APRIL 2011

Underground Space - 1st Scientific Symposium on Tunnels and Underground Structures in South-East Europe

The intention of this symposium is to proliferate the knowledge of tunnelling and use of underground space which is already the state-of-the-art in other parts of the world. The topics focus on all aspects of durability of structures from conceptual stage to design, construction, operation and maintenance phases. Contact: Symposium Secretariat manager, Ms. Tanja Rabar
Tel: 00385-51-322-854
Email: tanja.rabar@hubitg.com

21 - 26 MAY, 2011

WTC 2011 Helsinki - Underground spaces in the

service of a sustainable society

The Finnish Tunnelling Association awaits you in Helsinki. A boom in tunnelling is currently underway in Finland. In this exciting environment WTC 2011 has been organised. General subtopics to include: planning the usage of subterranean spaces, municipal services, operational technologies, traffic and logistics, geologic disposal of nuclear waste, renewable energy, project management. Website: www.wtc11.org
Booking / accommodation enquiries:
Tel: +358-9-5607500 Email: wtc11@congreg.fi

19 - 22 JUNE 2011

RETc 2011 - Rapid Excavation and Tunneling Conference and Exhibit, San Francisco, California

RETc is an international forum for the exchange and dissemination of developments and advances in underground construction. For more information contact event organiser: RETc Exhibits, 8307 Shaffer Pkwy, Littleton, CO 80127, 303-948-4213, gury@smenet.org

29 - 30 JUNE 2011

Underground Construction Conference and Exhibition, London

The eyes of the global tunnelling industry are swivelling towards the UK with some of the world's largest underground construction projects getting underway. Event includes: technical and design developments in underground construction, tunnel operation and maintenance, sustainable development and minimising the impact of underground works, a world wide tunnelling perspective, UK projects - today and the future, ground investigation, treatment and monitoring. Tel: +44 (0) 207 973 6695
Email: g.stringer@hgluk.com
Website: 2011.tunnellingshow.com/

12 - 16 SEPTEMBER 2011

6th International Symposium on Sprayed Concrete, Tromsø, Norway

Main themes will be design, construction and durability of wet-mix sprayed concrete in underground structures. The Norwegian Concrete Association is currently revising the Publication No. 7, Sprayed Concrete for Rock Support. This will be debated during the symposium. Contact: Siri Engen Email: siri.engen@tekna.no Website: www.sprayedconcrete.no

26 - 27 OCTOBER 2011

XI International Conference Underground Infrastructure of Urban Areas, Wrocław, Poland

A forum to develop an exchange of experiences and provoke a discussion on the topics related to building of tunnels and underground infrastructure in cities. Tel: 0048 71 320 29 14
Email: andrzej.kolonko@pwr.wroc.pl

BRITISH TUNNELLING SOCIETY

17 FEBRUARY 2011: BTS / MinSouth Joint Event - The Ingula Pumped Storage Scheme

The Ingula Pumped Storage Scheme is currently the largest tunnelling project in South Africa. The location is 400km south-west of Johannesburg and 80km north-east of Lesotho. There are over 12km of tunnels up to 9.4m diameter, 4 shafts (up to 20m dia x 190m deep), 2 large caverns, requiring substantial support. The geology is primarily a relatively weak sedimentary rock, with dolerite dykes and sills.

17 MARCH 2011: Green Park Step Free Access

The works included a south-eastern extension to the existing ticket hall incorporating a ramp from the adjacent Green Park directly into the station, and the installation of two lift shafts. This presentation will discuss the development of the design and construction of the elliptical lift shaft and stub tunnel using SCL methods & escalator jacking system and the instrumentation and monitoring equipment employed.

21 APRIL 2011: Harding Prize Competition

The Competition is open to all aged 33 or under at the end of 2010. Entrants must submit an original paper relating to any aspect of tunnelling which they consider of interest to those in the tunnelling industry. The closing date for submission of papers is 28th February 2010.

19 MAY 2011: BTS AGM + Limerick Immersed Tunnel

The Limerick Tunnel will provide a new road crossing under the River Shannon The tunnel comprises five 100m long immersed tunnel elements, a cut and cover tunnel and approach ramps on each bank.

29 JUNE 2011: High Speed Railway Tunnels in Spain

With the opening of the new Levante line, the Spanish High Speed Railway network has become the longest in the world. HSR lines with their demanding alignments require the design and construction of an unusually high number of tunnels, some of which are amongst the longest and more important in the world.

This presentation provides information of three good examples of the tunnels recently built in Spain: Guadarrama tunnel, Pajares tunnel and finally Atocha-Chamartan tunnel. This is an evening BTS Presentation being held at the "BTS Underground Conference 2011" on 29th to 30th June 2011. It is a 2 day conference being held in the Earls Court Exhibition Centre.

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', Boundary House, 91-93 Charterhouse Street, London, EC1M 6HR, United Kingdom. Fax: +44 20 7936 6826 Email: editor@tunnelsonline.info Web: www.tunnelsonline.info

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