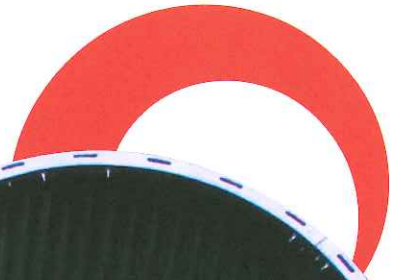


INTERNATIONAL EDITION

June 2014

# Tunnels

AND TUNNELLING



*Sifting through the developments and options available for spoil removal*

**SPOILED  
FOR CHOICE**

Scandinavia • Ground improvement



# 14.4 m

A mission in Auckland for 'Alice', whose large diameter makes it **one of the biggest TBMs** in the world.

# efficient

EPB Shield S-764 with an electrical drive and independent culvert gantry for laying the tunnel floor, from the start making good headway of up to **90 m a week**.

# mega-project

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## NEXT GENERATION

**R**ecently, various reports have been released that confirm the ever-widening gap between the Millennial generation and the preceding Baby Boomers. Those born approximately between years 1980 and 2000, are more likely to prefer living in an urban area, and prefer public transit to car ownership.

Dubbed Millennials, as they've reached their teens and 20s during the turn of the Millennium, the younger subset of the population is driving significantly less than previous generations.

It's not that Millennials are interested in having access to public transport, they want to abandon the road entirely. In April The Rockefeller Foundation and Transportation for America released a new survey that explores Millennials' perceptions and attitudes toward transportation. Almost half (46 per cent) of the surveyed vehicle owners "would seriously consider giving up their cars" if they could count on a range of transportation options, and a large majority say it is important for a city to offer opportunities to live and work without a car. The same survey found 54 per cent would consider moving if another city had more and better transit options.

Automakers say this is simply a matter of economics, and that once this generation pays back its student loans, car purchases will increase. However, new options for car-sharing and ride-sharing are popping up across the US, such as Uber and Lyft, and that's not to mention bike sharing programs popular in cities worldwide. These programs, which appeal to a generation addicted to smart phones, will

Nicole Robinson  
Americas Editor



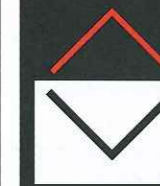
certainly retain customers, even as disposable income rises.

While increasing demand for public transit is generally good news for the tunnelling industry, it's not without hurdles. With fewer drivers there is less revenue for funds like the gas tax. That 18.4 cents a gallon, which goes to the Federal Highway Trust Fund, subsidises highways, as well as mass transit.

It also takes less time and money to implement, say, a protected bike lane, than a light rail line, especially if there is an underground component. And a small tech firm can devise an app-based ride sharing service in a matter of months or even weeks. There is a generation of people welcoming a change in the transportation status quo, but it does not have the patience for errors

editor@tunnelsonline.info

What do you think? Send your views to the editor and join the debate



### This month...

#### 20 YEARS AGO

The British Tunnelling Society debated the motion 'NATM is not appropriate for use in London Clay', which was proposed by David Fawcett, seconded by Christopher Smith, and opposed by Gerhard Sauer and Alan Muir Wood. The debate was set against major underground works being undertaken for the first time in London Clay - the Heathrow Express Link and Jubilee Line Extension - which Fawcett said might amount to "experimenting under our heritage [London]". In response, a long history of successful use of NATM in soft ground under cities in Europe was presented by Sauer. Smith then asked what can be done when a 20m<sup>2</sup> face is open, without support, and, in quickly-changeable conditions, begins to move. Could one have total confidence that the buildings above are safe? In the end, however, the motion was overwhelmingly defeated. *Tunnels and Tunnelling*, June 1994, p.22

#### 30 YEARS AGO

Editor David Martin reflects on the advances of the tunnelling industry in the then 15 years since the launch of the magazine. Although full face TBMs have been with us since the late 1950s following the work of James S. Robbins in the USA, it has been the period 1969-1984 that has seen moles given a chance to build up a track record that allows them to be recommended where conditions are suitable. He ends that "we still don't know if moles are better than drill & blast". *Tunnels and Tunnelling*, June 1984, p.5

#### Cover

In this issue Patrick Reynolds explores some of the options that are available when thinking about mucking



#### Next issue

In the next issue *Tunnels* looks at the North American tunnelling market as the industry heads to NAT in Los Angeles. Meanwhile, Editorial Advisory Board chairman Myles O'Reilly has written on wartime tunnelling, timely for the anniversary of the start of WW1

## Pioneering Underground Technologies



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Bernadette Ballantyne, technical journalist  
Sweden's capital city is going underground to improve transport connections to Stockholm meaning that a tunnelling surge is on its way to this part of Scandinavia
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Desiree Willis, Robbins  
High atop the mountains in northern Norway, a tunneling project harkens back to the days of mechanised tunneling in Scandinavia. The crew onsite battles winter temperatures and works to maintain spares and other supplies at the remote jobsite near the Arctic Circle

## Technical

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Drilling innovations, sea platform working and complex logistics were needed for grout injection by the contractor to improve porous ground conditions experienced by Miami's new port tunnel

## Insight

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Patrick Reynolds, technical journalist  
Tunnelling challenges are pushing through ever more solutions, and choices when it comes to mucking out to provide food for thought for logistics managers



## Contributors

### ADRIAN GREEMAN

Adrian is a former editor of *Tunnels* and a longstanding regular contributor. A freelance technical journalist, he produces articles for a range of subjects but is primarily focused on international civil engineering projects, and has written for a number of leading titles. In this issue he explores the grouting work undertaken to improve the incredibly porous ground conditions encountered on the now completed Port of Miami Tunnel project. Read him on p. 48.

### DESIREE WILLIS

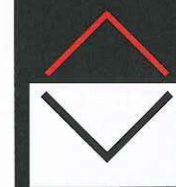
Desiree has worked for The Robbins Company for the past eight years as a technical writer. Documenting tunnelling projects for rail, water, sewer, road and other types of civil infrastructure. She has explored a wide variety of editorial topics in the tunneling industry for *Tunnels*, from projects under high cover to soft ground TBM design. In this issue she looks towards a possible new dawn for mechanised tunnelling in Norway, as Robbins launches its first TBM in the country for 22 years. Read her on p.44

### BERNADETTE BALLANTYNE

Bernadette is the editor of *Tunnels'* small bore sister publication, *Underground Utilities*. She also works as a freelance technical journalist specialising in infrastructure and construction. Recent articles by her include detailed supplements on high speed rail, international heavy lifting of tunnel boring machines and tunnelling in the Middle East. In this issue, she covers the underground solutions being undertaken to improve Stockholm's transport connections as a rush for tunnels starts in Europe's north. Read her on p.37.

What do you think? Send your views to the editor and join the debate

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## ITA SAFETY GROUP SUSPENDS WORK

**Global** The ITA Working Group on Health and Safety in Works (WG5) has been forced to temporarily suspend future activities due to poor attendance. Speaking at the ITA General Assembly in Brazil last month, group animateur Donald Lamont also warned that the level of scrutiny afforded the current documents up for review was not as great as he had hoped, and could result into a delay of up to a year for the work programme.

Current work programmes will be completed. "WG5 is working on a revision of the joint ITA/BTS CAWG guidelines

on high pressure compressed air work for which the target date for publication is WTC 2015," said Lamont. "We are also working on a guideline for safety requirements of underground vehicles in conjunction with ITATech. Publication is planned for WTC 2016.

"The suspension of future new activity is only temporary as we had not enough of the core membership in Brazil to allocate tasks other than those already allocated. Animateurs and vice animateurs do most of the work."

Lamont told *Tunnels* that he thought the poor attendance was "a matter of

location/distance [of WTC 2014], and employers being unwilling to fund the trip." He added, "With hindsight I think Iguassu was possibly a more favourable location than Sao Paulo despite the additional travelling involved."

The WG5 report was also critical of the absences of health and safety content in both the pre WTC training course and in general ITACET courses. Lamont noted that the General Assembly had previously agreed that every ITA training course immediately prior to WTC would include a session on health and safety. This has not happened since WTC Vancouver.

### Turkish mine disaster and Rio sinkhole shadow WTC 2014

**Turkey-Brazil** Two disasters shook the World Tunnel Congress in Brazil last month. A sinkhole appeared on the Rio de Janeiro Metro Project, while in Europe, more than 300 coal miners were killed in an explosion and fire in western Turkey.

A minute of silence was held prior to the second session of the ITA General Assembly on 14 May. The catastrophe was felt keenly, given the 2014 Congress's major focus on future tunnelling opportunities in the mining sector.

The Soma Mine Disaster as it is now known struck on 13 May, with an underground explosion, which caused a fire to burn until 15 May. Nearly 800 miners were underground at the time.

According to the Turkish statistical institute's 2013 report on workplace safety, some 2.3 per cent of all workers in the country had been injured at work that year, with 10 per cent of accidents occurring in the mining sector. Over 13,000 miners had some sort of reportable accident in 2013 in Turkey, and before the Soma disaster, there had been 1,308 fatalities in the industry since 2000.

Protesters were on the

streets, and the town in 'lockdown' as *Tunnels* went to press following the end of search and rescue operations.

In Rio de Janeiro, on 11 May at 3am two sinkholes appeared in Barao de Torre Street, Ipanema, during excavation work on Line Four. Nobody was injured, material damages were minor and announced to be solved on 12 May.

Tarcisio Celestino, chair of WTC 2014's organising committee, told the gathered press that 100cu.m of concrete fill had been sufficient to halt the problem, which had apparently been caused as the EPBM was entering sand. The precise details were being analysed by specialists as *Tunnels* went to press.

### Miami to open tunnel

**USA** A private ceremony marked the completion of the Port of Miami tunnel project on May 19.

After decades of planning and four years of construction, the Port of Miami Tunnel was expected to open to the public as *Tunnels* went to press.

Prior to the tunnel being built, the only way into the Port was through Port Boulevard. That caused heavy truck traffic, cruise line buses and private cars to congest the narrow Central Business

District. The project consisted of twin tunnels under Government Cut among other infrastructure developments.

The PortMiami Tunnel will improve access to and from the Port, serving as a dedicated roadway connector linking the Port with the MacArthur Causeway (State Road A1A) and I-395.

The Port is located on Dodge Island, a 518-acre island in Biscayne Bay and connected to the city of Miami solely by the Port Boulevard Bridge.

All traffic currently enters and exits the island on the existing bridge.

Construction is on schedule and within budget.

### News briefs

#### GREAT BRITAIN

London Underground (LU) carried more customers and ran more train during the last year than ever before, according to new figures published by Transport for London (TfL) earlier this month. The end of year figures show that LU carried 1.265bn passengers in 2013-14, compared with 1.229bn the previous year. The year-on-year growth of three per cent continues the rising demand for tube services, with passenger numbers up by a third over the last ten years, TfL stated. The report also revealed that LU also ran more services in 2013-14, with nearly an extra 600,000kms operated over the year.

#### IRELAND

The longest tunnel ever built in Ireland has just been completed in north Mayo as part of the Corrib gas project, Vermilion Energy announced recently. The tunnel, which reached its total length of 4.9km in May, will serve as a conduit for the gas pipeline between the Bellanaboy gas processing facility to the offshore pipeline landing valve at Glengad. Based on the current deterministic schedule for the project, Vermilion Energy expects first gas from Corrib in approximately mid-2015. The tunnel has been under construction since January 2013. Vermilion Energy stated that activities need to be completed prior to initiation of production at Corrib. These activities include demobilisation of the TBM, running flow and umbilical lines within the tunnel, grouting of the tunnel, certain offshore well workover activities, and receipt of final authorisations for start-up of the Bellanaboy gas facility.

**Tunnelling work on SBK Line enters final year**

**Malaysia** There is only one more year to go before tunnelling work of the Klang Valley MRT's Sungai Buloh-Kajang line (SBK Line), concludes, according to reports by local media.

By the end of this year only two TBMs will still be mining, and the last unit was set to be retrieved from the ground in May 2015, the reports said, adding that five TBMs are currently working on forming the 9.5km-long pair of tunnels.

Supervised by project owner Mass Rapid Transit

Corporation Sdn Bhd, the contractor for the underground portion, MMC Gamuda KVMRT (MGKT), is currently working around the clock to ensure that the TBMs are running at optimal efficiency.

The ground conditions for this project are particularly challenging because the SBK Line tunnels have to pass through two major soil formations: the Kenny Hill sedimentary rock and sand Lumpur limestone formation.

While the former is a typical and more predictable geological formation found widely within the vicinity

of Kuala Lumpur and in the Klang Valley, the Kuala Lumpur Limestone formation is highly weathered karst.

"The great challenge comes when a TBM punctures through into these voids - equilibrium is rapidly disturbed. The groundwater and the slurry required by the machine to maintain working pressure will dissipate quickly through the network of channels," says Ubull Din Om, MGKT's general manager for underground works.

"While mining through karst is already very challenging, it becomes doubly difficult when a TBM has to pass through karst

that is overlaid with other soil profiles," Ubull said.

In May, a pair of TBMs were due enter an area where undulating karst is layered with the material of the Kenny Hill formation.

This difficult area lies close to a commercial area. At this location, the tunnels will be stacked one on top of the other, with the crown of the upper tunnel just 16m below the ground's surface.

On average, the tunnels run about 30m below ground, with the deepest portion of 45m at the Pasar Rakyat MRT station.

Since excavation works began in 2012, MGKT has not encountered any major geological problems.

However, Bukit Bintang remains a highly formidable stretch to tackle.

## CONCRETE LINER COMPLETED ON BILLY BISHOP TUNNEL

**Canada** The Toronto Port Authority (TPA) announced completion of the concrete liner in the Pedestrian Tunnel at Billy Bishop Toronto City Airport (BBTCA) last month. With the completion of the liner, the tunnel project will now move into the mechanical and electrical installation phase before final finishes are put in place this winter.

Excavation began in early 2012 on the mainland and island shafts. Once the shafts were dug, two purpose-built, Canadian-made TBMs dubbed 'Chip' and 'Dale' were launched to bore the seven interlocking "tunnel drifts," forming the unique arched crown design of the main tunnel. Three of the tunnel drifts were built to include new City Of Toronto sanitary and water mains. Excavation of the tunnel was completed in October 2013, and waterproofing and reinforcing steel layers were installed.

"Just six months ago, we were in the process of carving through rock. Today, with the concrete ceiling, walls and flooring complete, the tunnel is quickly transforming into what will be a first-class piece of infrastructure Torontonians can be proud of," said Geoffrey Wilson, TPA president and CEO. "The pedestrian walkway is about making the Billy Bishop Toronto City Airport traveller experience even better and will allow people to get to and from the airport when they want and how they want. It is also an important component of our traffic management strategy as it evens out the flow of passengers and alleviates the congestion stemming from travellers arriving and departing in waves according to the ferry schedule."

The concrete liner encases the 550ft

(167.6m) horizontal tunnel expanse that runs under the Western Gap connecting the mainland to the airport. The concrete was poured in 16 sections by a 110t, 12m, arch-shaped hydraulic machine that forms an artificial surface onto which the concrete is pumped to create the ceiling and walls. On average, each section takes two days to complete leaving a solid concrete liner over the rock. Approximately 2,000 cu.m of concrete was poured to create the liner.

When it opens, the pedestrian tunnel will have four moving sidewalks travelling at 2.3km per hour. From a bank of six elevators on the mainland side, travellers will go 100ft (30.5m) down to access the tunnel and travel along the passageway to escalators which take travellers to the airport's check-in area.

The complete journey will take less than six minutes, and will dramatically improve passenger flows.

The next phases of the project will include construction of the connecting terminal structures, installation of the moving walkways, escalators and elevators and landscaping, as well as electrical, mechanical and finishing work.

The tunnel project will not be paid by taxpayers but is rather financed through an innovative public-private partnership agreement between the TPA, Forum Infrastructure Partners and lead contractor PCL.

A portion of the existing Airport Improvement Fee paid by departing passengers will also go towards the tunnel's construction.

Once in operation, the tunnel will use 100 per cent green energy supplied by Bullfrog Power Inc.

**NFM Technologies secures TBM contract, its first in Saudi Arabia**

**Saudi Arabia** NFM Technologies has just signed a contract with the Metro Riyadh Line 3 consortium to supply a 10.16m diameter TBM to excavate the red line of the Saudi capital's metro system, the company announced in April.

NFM Technologies said it will supply an EPBM. Weighing 1,400t and 100m long, the TBM will excavate to a depth of 40m in soil mainly composed of limestone and silt.

The machine will be built, assembled and tested in the NFM Technologies workshops in Le Creusot, France.

Delivery to the client is scheduled for this summer.

The consortium features companies including Impregilo SpA, Larsen & Toubro and Nesma & Partners. It is responsible for building the 40.7km of Line 3, the longest of the six-line metro project.

Line 3 runs east-west from Madina Al Munawra to Rahman Al Awal Road, with 20 stations and a 6km underground section.



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GRANDS PROJETS

## CALGARY'S AIRPORT TUNNEL OPENS

**Canada** The 620m-long Airport Trail tunnel under the new runway at the Calgary International Airport in Calgary, Alberta, opened to traffic on May 25.

The City celebrated the completion of the 36m-wide tunnel with a public event on May 24 to recognise the hard work, commitment and cooperation of many people who delivered this piece of vital infrastructure. Thousands of Calgarians

attended the opening.

The Airport Trail tunnel was also one of three City of Calgary projects to receive 2013 Award of Excellence honours from the 2013 American Concrete Institute (Alberta Chapter).

Tunnel excavation involved the removal of more than 600,000cu.m of rock and earth material. Concrete work on the structure itself began with the installation

of footings followed by forming and casting of the tunnel walls and roof. A total of 50 concrete sections were poured. Each tunnel section required 850 cu.m of concrete, which was delivered by about 80 trucks over a 12-hour period. The first concrete pour for the tunnel walls and roof took place on February 24, 2012, and the last pour was completed on October 30, 2012.

### Waterview TBM stops for maintenance

**New Zealand** Tunnelling on New Zealand's largest roading project – the NZ Transport Agency's Waterview Connection in Auckland – stopped last week for essential maintenance work on, Alice, the project's huge TBM. Work is expected to resume shortly.

Hundreds of steel fibre brushes installed on the shield of the TBM need to be replaced. Tommy Parker, the NZ Transport Agency's group manager for Highway and Network Operations, said: "Tunnelling on this scale is a complicated task, and some wear and tear on the machine is inevitable. We decided it would be prudent to replace the brushes now, before we possibly encounter more onerous groundwater conditions later."

Approximately 800m of tunnel has now been constructed. About a third of the 12,000 concrete segments that form the southbound tunnel's lining have been erected.

"The maintenance work on the steel fibre brushes will not affect other construction work in the tunnel. In fact, we can use the time to make faster progress on the concrete service culvert that is being built behind Alice," said Parker.

The culvert will carry the services needed to operate the two completed tunnels, which are due to open in early 2017.

### Black & Veatch and AECOM win DTSS contract

**Singapore** A joint venture between Black & Veatch and AECOM has been selected by PUB, Singapore's national water agency, to provide engineering services for Phase 2 of the Deep Tunnel Sewerage System (DTSS), it was announced June 3.

Freeing up land for other higher-value developments, supporting the production of NEWater, improving energy efficiencies and potentially leveraging the water-energy-waste nexus are some of the key sustainability goals of DTSS Phase 2.

"The project's vision underlines PUB's innovation and global leadership in sustainable water solutions," said Cindy Wallis-Lage, President of Black & Veatch's water business.

"It is a privilege to team with AECOM and PUB in setting a new standard in reliable, flexible and energy-efficient infrastructure that promotes water sustainability for the future."

"We have assembled a compelling joint venture team of world-class local and global experts, who look forward to delivering a sustainable infrastructure solution," said Michael S. Burke, AECOM president and chief executive officer. "We are honoured to be a part of the DTSS project, which will enhance Singapore's water sustainability and resilience – solidifying its place as a

leader in the global water industry."

DTSS Phase 2 will extend DTSS to the western side of Singapore through a 30km-long South Tunnel, 70km of link sewers, the Tuas Water Reclamation Plant (WRP) and a 12km (estimated) deep sea outfall. The entire DTSS will result in a 50 per cent reduction in land taken by used-water infrastructure with three centralised collection and treatment points: Changi WRP in the east; Kranji WRP in the north; and Tuas WRP in the west.

A NEWater factory will be integrated with the Tuas WRP and contribute to Singapore's long-term goal of increasing NEWater production to meet up to 55-percent of its total water demand.

In addition, working with Singapore's National Environment Agency, an Integrated Waste Management Facility will be co-located at the Tuas WRP site. This offers potential opportunities to integrate used-water and solid-waste treatments to maximise energy and resource recovery.

The B&V+AECOM JV will conduct a feasibility study and preliminary design as part of the first stage of the project. As the lead consultant, the team will programme manage the delivery of DTSS Phase 2 in the second project stage.

Supporting Black & Veatch and AECOM will be Ramboll, a leading consulting engineering company from

Denmark and KPMG. During the course of the project, the team will also explore ways to collaborate on ideas with key tertiary institutions in Singapore.

The contract was signed today at a ceremony at Singapore International Water Week 2014, which includes guest of honour, Dr Vivian Balakrishnan, Minister for the Environment and Water Resources.

### TBM makes breakthrough on St Louis sewer

**USA** SAK Construction made a breakthrough on May 19 on a force main tunnel for the St. Louis Metropolitan Sewer District's Lemay wastewater treatment plant.

The 11ft diameter TBM's drive of 3,200ft passed beneath the River Des Peres in south St. Louis. Tunnelling had launched in February at a 175ft-deep south shaft.

Scheduled for completion in 2015, the force main will replace one previously constructed in the 1960s, which will be taken out of service and inspected.

### Crossrail starts shortest tunnel drive

**Great Britain** Crossrail started its shortest tunnel drive from Limmo Peninsula towards Victoria Dock Portal in east London this month.

TBM Jessica will create the 900m tunnel forming part of the south-east spur of London's new rail line.



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**Nepalese highway builder focuses on foreigners for finance**

**Nepal** Client Nepal Purbadhar Bikash Co. Ltd. (NPBCL) has turned to foreign investors to develop the Kathmandu-Kulekhani-Hetauda Tunnel Highway after it failed to woo local investors.

Lal KC, vice chairman of NPBCL, said in Kathmandu on 19 May that it decided to approach multinational investors to finance the project as its effort of mobilising internal resources turned futile.

He further added that NPBCL has submitted a new plan of collecting NPR 26.25bn (USD 270M), or 75 per cent of the total project cost of NPR 35bn, from foreign investors to the Ministry of Physical Infrastructure and Transport (MoPIT).

As per plan, the amount should be injected into the project by the end of December 2016 - the targeted completion date of the 58km-long highway.

To meet the annual target, foreign investors should pour in about NPR 7bn (USD 74M) annually, which is about 36 per cent of the total FDI commitments made by the foreign investors in the last fiscal year. Nepal received foreign direct investment commitment worth NPR 19bn (USD 2bn) in the last fiscal year.

NPBCL had made a presentation on its fund-

raising plan at the MoPIT in mid-May. It, however, has not presented complete financial closure as mentioned in the license document awarded to the NPBCL last year.

KC said they would allocate 5 per cent of shares to Nepali banks and financial institutions. As per the new plan, NPBCL also proposed to reduce equity contribution from promoters and general public to 20 per cent. In the previous plan, equity contribution from promoters and general public had been fixed at 50 per cent. This means equity investors, including promoters, will have to invest NPR 7bn.

Earlier, NPBCL had floated a charismatic plan of developing the project through local investment and by using skills of Nepali engineers and technicians. But private sector cold-shouldered NPBCL's proposal to make investment in the project. It has so far collected about NPR 300M in cash and NPR 7bn in commitments.

However, KC argued that they could not raise 50 per cent equity investments due to the existing legal hurdles.

"Our estimation was a valid one; there is sufficient fund in the market. But people were not much aware of our new product," KC said.

**Work on drainage tunnel project inaugurated**

**Qatar** Engineer Nasser bin Ali Al Mawlawi, president

of Public Works Authority - Ashghal - on 20 May inaugurated excavation works on a construction site in Al Thummama for Mesameer Surface and Ground Water Tunnelling, a significant project undertaken by Ashghal to enhance Qatar's drainage network.

Al Mawlawi was accompanied by Guido De Sanctis, Italian Ambassador, and senior officials from Ashghal, including Jalal Yousef Salhi, Director, Infrastructure Affairs, and Hamad Mohamed Al Tamimi, Director, Asset Affairs.

Also present were representatives from Ashghal's Roads and Drainage Operations and Maintenance Department, CDM Smith, Project Consultant, Salini Impregilo Construction Company, project contractors, and Herrenknecht, German manufacturer of tunnel boring machines (TBMs) being used to excavate tunnels. Excavation is being carried out by Al Thummama, one of the two technologically advanced TBMs being used for the first time in Qatar and specially designed and developed for the project.

The Mesameer tunnel for surface and ground water is one of the key drainage projects within Ashghal's plans to upgrade Qatar's drainage network.

The tunnel will run under F-Ring Road, stretching 9.7km. It will run 5.4km from Al Thummama to the

west and 4.3km to the east to the planned pumping station near new Hamad International Airport.

The tunnel will alleviate Doha's storm water by transporting it from a 170 sq.km of catchment area, covering southern and western parts of greater Doha. It will be linked to existing and planned drainage network in the areas it will traverse.

To allow access for inspections and regular maintenance of the tunnel, an operations and maintenance plan has been developed to ensure satisfactory operation of all elements. This will be facilitated through 21 access shafts linking ground level to 20m to 30m depth of the tunnel.

Named after the areas where the TBMs will operate, and measuring 4.5m diameter and 121m long (including support equipment), 'Al Thummama' and 'Al Rawada' possess a significant capacity to excavate tunnels without causing any adverse effect on surrounding structures and disruption to traffic.

The specially manufactured TBMs operating through pressure balanced excavation technology are ideal for Doha ground conditions at a depth of 30m. This technology will facilitate the construction of essential infrastructure tunnelling which is paramount to accomplish a sophisticated tunnel network.

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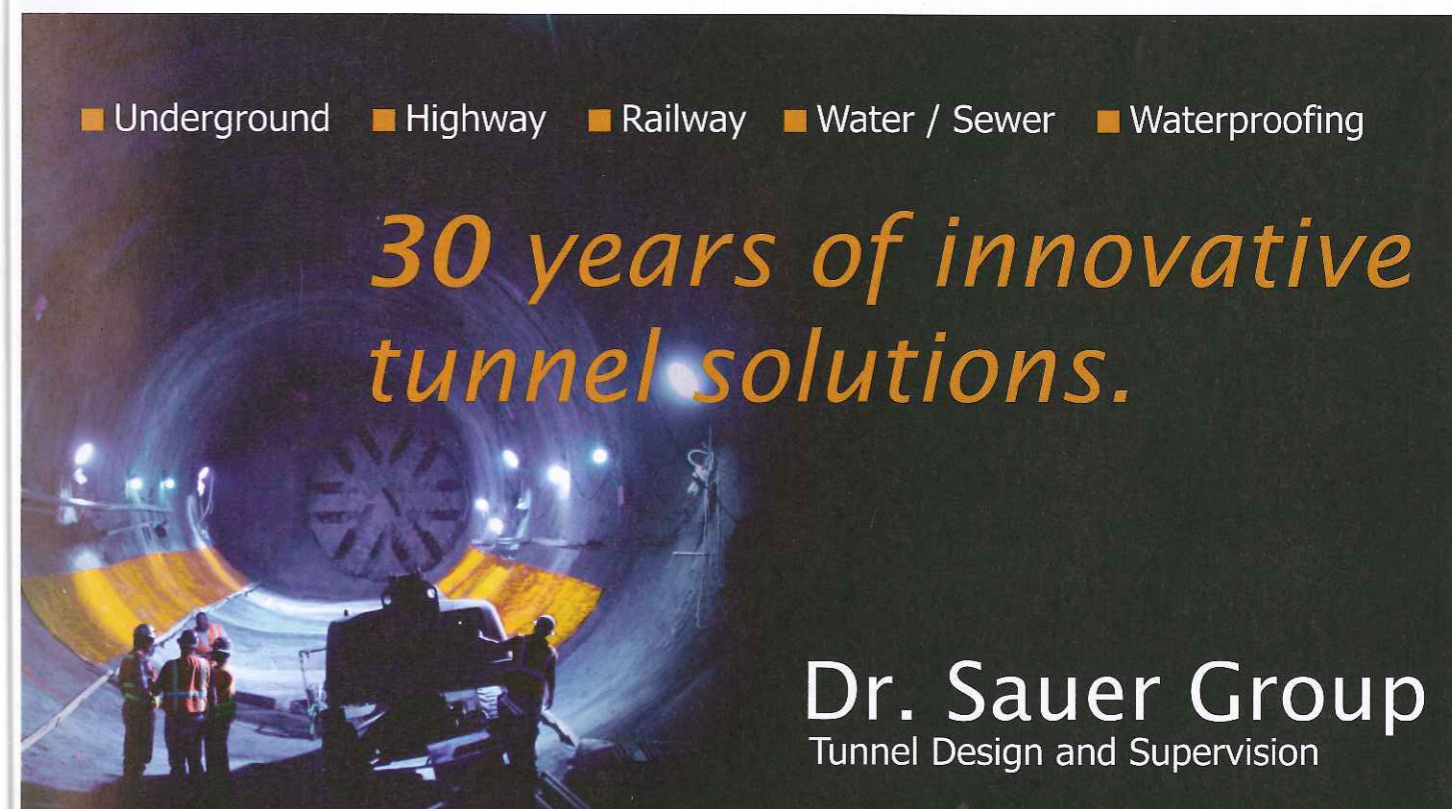
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**JAPAN TO INSPECT AGEING TUNNELS**

**Japan** Inspections of ageing road infrastructure (bridges and tunnels) are urgently needed to promptly work out and implement safety measures. This is an issue that weighs heavily on local governments around the country, according to a report in the Japanese daily newspaper Yomiuri Shimbun.

Effective from July, the Land, Infrastructure, Transport and Tourism Ministry will make it obligatory for bridges

and tunnels under the administration of prefectural governments as well as those managed by city, town and village municipalities to receive safety checks every five years.

Local governments are supposed to assess the safety of bridges and tunnels in four stages, and take countermeasures corresponding to the respective stages.

Some 43 per cent of bridges throughout the country and 34 per cent

of the country's 10,000 road tunnels will be more than 50 years old in 10 years from now, compared with 18 per cent of current bridges and 20 per cent of current tunnels.

It should be noted that it is not the central government but local governments that are in charge of administering 90 per cent of the tunnels. Local entities must lose no time in buckling down to the task of dealing with ageing infrastructure.

## BILFINGER WINS EIGANES CONTRACT

**Norway** Bilfinger has won an order in the Norwegian city of Stavanger for the construction of the Eiganes Tunnel. The tunnel is being constructed to reduce the volume of traffic in the city.

The European Route 39, one of the main traffic arteries on Norway's southwest coast, will pass through the new tunnel.

The project has a total value of EUR 230M (USD 329M). It will be carried out by a JV in which Bilfinger holds a 60 per cent stake and the Norwegian company Stangeland 40 per cent.

Work on the 5km long twin tube tunnel includes construction of several access ramps as well as further connector tunnels. A 2.5km long new motorway section will also be built as will bicycle and pedestrian paths.

"Bilfinger is specialised in smart civil engineering projects in the area of mobility and looks forward to contributing its expertise to the construction of underground traffic routes", said Joachim Enekel, member of the executive board at Bilfinger. The partner, Stangeland, will assume responsibility for earthworks and road construction.

The project will be completed in 2018. In addition to relieving traffic pressure in Stavanger, the Eiganes Tunnel is also expected to provide an improved inner city connection to the existing Ryfas Tunnel, an important transport link in southwest Norway.

### Caldecott Fourth Bore tunnel wins award

**USA** Tutor Perini Corporation announced on May 26 that its subsidiary, Tutor-Saliba Corp., recently received the Project of the Year Award from the California Transportation Foundation for the Caldecott Tunnel Fourth Bore Project.

This award recognises the premier transportation project among projects throughout California. Tutor-Saliba constructed this major project for the California Department of Transportation (Caltrans). Tutor-Saliba is led by Tutor Perini's Civil Group CEO, Jack Frost. The Caldecott Tunnel Fourth Bore opened to traffic on November 16, 2013, on schedule and under budget, saving motorists on average 10 to 15 minutes of commuting time. The project included the construction of a 3,399ft (1,036m) long, 41ft (12.5m) wide, two-lane concrete tunnel on the heavily traveled State Route 24 in Alameda and Contra Costa counties. The project

included seven emergency cross passages connecting to the existing third bore, 16 retaining walls, soundwalls, two electrical substations, a two-story Operations, Maintenance and Control building and various roadway improvements.

The project also featured wide travel lanes, roadway shoulders, bright lighting, emergency exits along the length of the tunnel, and state-of-the-art fire and life safety systems. The tunnel's incident detection and response systems allow monitoring and response to threats inside the tunnel, including detecting and suppressing fires and other hazards, and provide real-time information to help motorists safely exit in an emergency.

### New Cairo metro line inaugurated

**Egypt** Cairo inaugurated the second phase of metro Line 3 on 7 May when Egypt's president Adly Mansour, prime minister Ibrahim

Mahlib and transport minister Ibrahim El Demeiri officially opened the 7.7km eastern section between Abbasiya and Haroun El Rachid station in the district of Heliopolis.

The USD 1.7bn five-station extension is expected to increase daily ridership on Line 3 to around 600,000 passengers. Civil works on the project were carried out by a French consortium of Vinci Construction and Bouygues Travaux Publics with Egyptian partners Orascom Construction and Arab Contractors. Construction started in 2009 and was completed five months ahead of schedule. One earth-pressure balance tunnel boring machine and one slurry TBM were used.

The initial 4.3km five-station section of Line 3 between Abbasiya and an interchange with Line 2 at Attaba opened in February 2012, and when all stages are complete the line will be 34km long stretching from the city's international airport to Mohandiseen and Embaba in Giza. In September 2012, Egypt's government signed a EUR 940M (USD 1.3bn) loan agreement with the Agence Française de Développement (French Development Agency) and the European Investment Bank to help fund the third phase, which will be 18km long western extension with 15 stations.

Line 3 is the first metro line in the city to be served by automatic trains. Seven additional eight-car trains have been acquired from Mitsubishi for phase 2.

### Delhi Metro awards third contract to HCC

**India** Hindustan Construction Company (HCC) Ltd has been awarded a USD 64M contract by Delhi Metro Rail Corporation (DMRC) for the design and construction of 1.54km long twin tunnel on Dwarka-Najafgarh metro corridor of phase III of Delhi Metro. This is the third contract for underground

metro received by HCC since October 2012 under the phase III development of Delhi Metro.

The twin tunnels will be constructed by TBM. The contract also includes construction of a major underground station, Municipal Corporation, which is 290m long and 30m in width. The station will be built at depth of 18m. The work will be completed in 36 months.

Arun Karambeklar, president and whole time director, HCC, said: "HCC has been undertaking challenging assignments in underground metro development and repeat order from DMRC reflects our ability to execute complex assignments. Last month, HCC completed the 'Eup-line tunnel' of CC30 package well ahead of all peers working on phase III."

Prior to this order, the company has received two contracts under the Phase III of Metro development for package CC30 on the Mukundpur - Yamuna Vihar corridor in October 2012 and package CC34 on Janakpuri West-Kalindi Kunj Corridor in February 2013. The company has already deployed five TBMs for these two packages.

### Ferrovial win Madrid-Galicia railbed project

**Spain** Ferrovial will build the railbed between the Padomelo Tunnel and Lubián, a section measuring 7.6km that passes through the municipalities of Requejo and Lubián, the company announced recently.

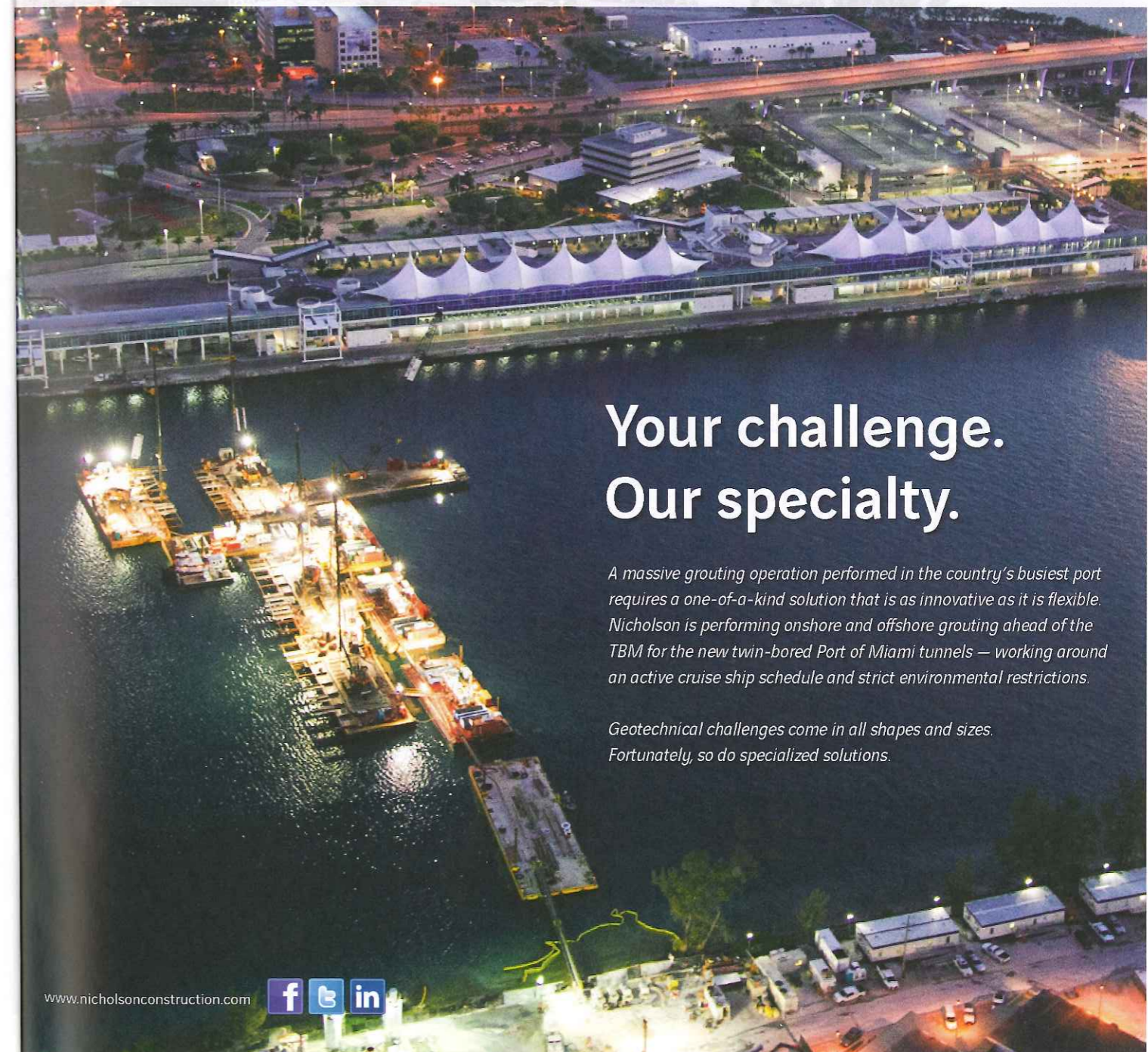
The contract includes the construction of a tunnel and two viaducts worth EUR 108.8M (USD 149.3M).

The project includes the construction of the right gallery of the Pardonelo Tunnel (6,407m long) and galleries connecting with the existing tunnel, which will be upgraded as part of a different project. This project is expected to be completed by the end of 2015.

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**London's Heathrow Airport to build M25 tunnel under new runway**

**Great Britain** Heathrow will tunnel a 14 lane stretch of the M25 motorway under a new third runway and increase compensation for homeowners if its extension plans get the go-ahead, a spokesman for the airport has announced.

Heathrow unveiled a revised GBP 15.6bn (USD 26.2bn) plan on the deadline for submission to the government's Airports Commission, which will choose between Heathrow or Gatwick for an extra runway in south-east England.

Under the Heathrow plan, a 600m, 14-lane tunnel would be built to replace an existing section of the M25, passing under the runway.

Government support for surface access improvements would be required and estimated at GBP 1.2bn (USD 2bn).

Heathrow will set up a GBP 550M (USD 926M) compensation fund for compulsory purchase and

improved noise insulation packages, an improvement in terms of compensation to similar infrastructure projects, including a 25 per cent premium on unblighted house prices.

It has also promised green space and flood protection.

**Iran to complete Istiqlol tunnel by next year**

**Iran** Caretaker of the Iranian embassy in Dushanbe, Seyed Mahmoud Sadri has announced that Iran would complete Tajikistan's strategic Istiqlol ("independence") road tunnel by the next Iranian year, which begins on 21 March 2015.

"During the recent visit of Tajik Transport Minister Khayrullo Asoev to Tehran and his meetings with senior Iranian officials about final work on the tunnel, the two sides agreed that Iranian experts resolve the problems of the project in several phases; on the same basis we hope to accomplish the project by next year," Sadri told Iran's Fars News Agency on 7 May 2014.

In April 2013, Iran and Tajikistan signed a Memorandum of Understanding (MoU) to complete the strategic tunnel in the Central Asian country.

The spokesperson for the lower house of Tajikistan's parliament Muhammadato Sultanov told reporters at the time that the agreement had been signed by the two countries to complete the 5km long Anzob tunnel, located 80km northwest of Tajikistan's capital city, Dushanbe.

The tunnel connects the Tajik capital to the country's second largest city, Khujand, travel to which, prior to the tunnel's construction, required travelers to cross the border into Uzbekistan in order to travel between the two cities. It is also a transit route between Dushanbe and Uzbekistan's capital Tashkent. Prior to construction of the tunnel, especially during winter, the danger of year-round avalanches led to periodic disruptions of commerce.

**STEC orders two giant TBMs for multipurpose tunnel project**

**China** Chinese contractor and manufacturer Shanghai Tunnel Engineering Co Ltd (STEC), has placed an order for two Herrenknecht 15.76m diameter Mixshield TBMs. The machines will be used for a large multifunctional tunnel in Wuhan, central China.

The twin bore double deck tunnel will feature a three lane highway on the upper level, and Wuhan Metro Line 7 below. The 2,590m long tunnel alignment runs up to 39.5m below the water surface in extremely complex soil. Water pressures of up to 5.3 bar are anticipated, and the tunnel runs through varying geological formations that feature sand and clay, mixed geology with mudstone, and conglomerates and sand.

It is expected that by 2017

the metro network of three lines will be extended to seven, from the current 73km to 215km in length.

**Nepalese officials visiting Japan to observe tunnel technology**

**Nepal-Japan** Eight Nepalese government officials have embarked on a week-long visit to Japan on Tuesday 20 May to learn about the tunnel construction technologies to be applied in the transport sector.

The observation visit supported by the Japan International Cooperation Agency (JICA) will be led by the Secretary of Ministry of Physical Infrastructure and Transport (MoPIT) Tulasi Prasad Sitaula. He will be accompanied by Joint Secretary MoPIT Rajendra Prasad Nepal, Director General of the Department of Roads Devendra Karki, Deputy Director General of the DoR Keshab Sharma and other officials.

Issuing a press statement, JICA said that the observation includes site visit at Hanabuchi-yama Tunnel in Miyagi Prefecture and tunnel and Sprial Bridge in Saitama Prefecture.

Tunnel specialists in Japan will deliver the briefings and important information to the Nepalese officials on tunnels and their construction technologies.

According to the statement, the Nepali government has long been planning to build a tunnel road on the Nagdhunga-Naubise Segment and has also conducted a feasibility study last year which concluded that a 2.3km tunnel linking Imakhel of Nagdhunga with Sisnekhola of Naubise was viable.

Japan is one of the most advanced tunnelling countries in the world 2,800km of road tunnel has been constructed up to 2012. "As Japan and Nepal's hilly topography is similar, experience is transferable."



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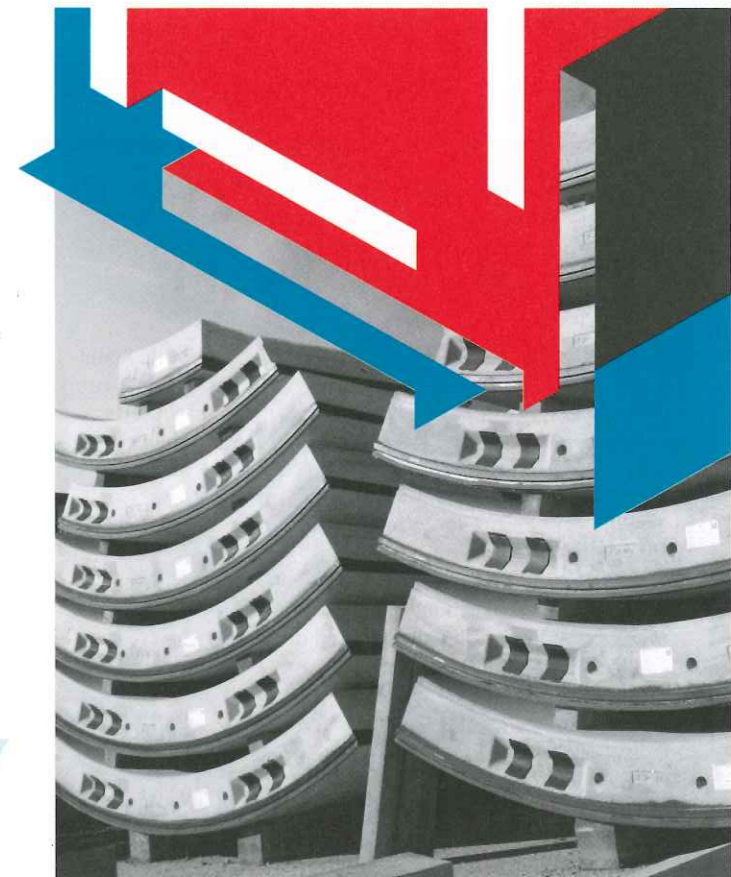
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**NEW YORK MULLS SYRACUSE OPTIONS**

**USA** New York State Department of Transportation (NYSDOT) has identified four tunnel solutions as part of its project to reconstruct Interstate 81 in the city of Syracuse, according to plans released on May 1.

The project concerns portions of I-81 -- built in the 1950s and 1960s -- that are deteriorating and in some sections do not meet current safety standards and are experiencing high accident rates. This is especially true of the 1.4-mile (2.25km) viaduct, near downtown Syracuse, NYSDOT said.

Two of the tunnel solutions run along Almond Street, one with a distance of about 2 miles, and the other of 1 mile. Both options would require cut-and-cover construction because of soil conditions and a high ground water table under Almond Street, as well as the need to treat and dispose of saline water, according to NYSDOT.

A third tunnel would be located under different street, but will still require cut and cover construction. The fourth solution would place I-81 in a new tunnel approximately one mile east of the existing highway, a minimum of 81ft below the surface where it could be bored through bedrock.

The costs of the different tunnel options range from USD 1.7 bn to 3.3bn.

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## COURT RULES ON BIG DIG DISPUTE

**USA** Tutor Perini announced on June 6 that its Perini-Kiewit-Cashman (PKC) Joint Venture recently prevailed in a court decision in its long-standing dispute with the Massachusetts Department of Transportation (MassDOT) regarding the Central Artery/Tunnel Project in Boston. Tutor Perini is the managing partner in the joint venture with a 56 per cent interest.

The dispute is related to a series of claims for additional contract time and compensation against MassDOT for work performed by PKC on a portion of the Central Artery/Tunnel Project. During construction, MassDOT ordered PKC to perform changes to the work and issued related direct cost changes, excluding time delay and inefficiency costs. A three-member Dispute Resolution Board (DRB) issued several awards and interim decisions in favor of PKC's claims. MassDOT had sought and was successful in having the DRB's binding awards vacated under the premise that the DRB exceeded its authority.

The decision this week, issued by Superior Court Justice Thomas P. Billings, affirmed the DRB's role as the binding arbitrator. In issuing its decision, the court ruled that each of the claims at issue for the Third and Fourth DRB panels are, in fact, subject to the binding dispute resolution process, and the DRB's awards on these claims are reinstated.

Commenting on the decision, Tutor Perini's CEO, Ronald N. Tutor, said, "The Joint Venture is extremely pleased with the judge's decision on the C11 case involving the Central Artery that has been ongoing in excess of 15 years. The Dispute Review Boards' decisions and awards, including accrued interest to date, exceed USD 80M as the amount due currently to our Joint Venture. This still leaves substantial additional non-binding DRB awards to be either adjudicated or resolved between the parties. This decision certainly vindicates our position and the vigor with which we pursued this litigation over all these years."

### Strabag scoops major European contracts

**Austria** On June 4, the bidding consortium consisting of Strabag and Salini Impregilo had officially been awarded the largest contract section to date for the Brenner Base Tunnel (BBT). For a contract value of about EUR 380M (USD 516.5M), the consortium will build the twin-tube rail tunnel between Tulfes and Pfons as well as a section of the exploratory tunnel, the new rescue tunnel running parallel to the existing Innsbruck bypass, and two connecting side tunnels. The construction time for the approximately 38k of tunnels is scheduled at 55 months, with work set to begin in the

second half of 2014.

The BBT, the heart of the new rail connection between Munich and Verona, runs for 55 km between Innsbruck and Franzensfeste (Fortezza). Including the existing Innsbruck bypass, which will connect with the BBT, the stretch of tunnel through the Alps comes to a total of 64 km, making it the longest underground railway connection in the world. The BBT consists of two single-track tubes, each 8.1 m wide, at a distance of 70 m from one another. The two tubes are linked at every 333m through connecting side tunnels as escape routes in emergencies. The nearly horizontal stretch of tunnel avoids the gradients of the existing, more than 140-year-

old Brenner Railway. The total cost for the project, which is to be completed in 2025, is estimated at EUR 8.6bn (USD 11.7bn).

As well, on June 5 it was announced Züblin Scandinavia AB, a Swedish subsidiary of STRABAG SE, had been awarded as leader and main shareholder in joint venture to build the Marieholmstunnel project, an immersed tunnel passing under the river Göta älv in the city of Gothenburg. The design & build agreement, which also comprises the mechanical and electrical works and which has a total contract value of about EUR 170M (USD 231M), was signed on 4 June 2014. Owner of the project is the Swedish road and railway authority Trafikverket, to which the tunnel is to be handed over in October 2020.

Marieholmstunnel is a road tunnel consisting of three lanes in either direction with a service tunnel in the centre and a designed lifetime of 120 years. Züblin will construct three tunnel elements of 100 m in length each on site in a drydock and immerse them at their final location in a trench dredged into the river bed. On either side of the immersed tunnel section, cut and cover tunnels will be built in deep excavation pits continuing through ramp and trough sections.

Special consideration will be given to the environment, e. g. the flora and fauna of the river Göta älv, during all phases of construction. The installation of all mechanical and electrical systems also forms part of the contract, which includes an option to operate and maintain the tunnel for five years after completion.

The project will start just after the handover of Trafikverket's Söderströmstunnel in Stockholm, a project of similar size and complexity executed by Züblin also as an immersed tunnel.

### Pahang-Selangor water transfer project nearing completion

**Malaysia** The Pahang-Selangor Raw Water Transfer Project is expected to be fully completed on 20 December, said Malaysia's energy and water minister, Datuk Seri Dr Maximus Ongkili.

The project, comprising four components or packages - raw water tunnel, Kelau Dam, Semantan River intake and pumphouse and twin pipeline - is 96 per cent complete, he added.

"In early August, as a trial, we will channel some 500M litres a day into Sungai Langat, which has three water treatment plants," he told local press reporters after visiting the project site at Bentong on 22 May.

Ongkili said the trial is a move to increase the water in the river because the country is expected to experience a dry spell from June due to the El Nino weather phenomenon effect.

When complete, the project will have the capacity to channel 1.89bn litres of water a day from Pahang to Selangor to meet the needs of consumers in Selangor, Kuala Lumpur and Putrajaya up to 2025.

### Wuhan Metro Line One extension inaugurated

**China** The Chinese city of Wuhan inaugurated the latest addition to its metro network on 28 May, when commercial services began running on the 5.7km northern extension of Line One from Dijiao to Hankou North.

With the opening of the three-station extension, traffic on Line One is expected to reach 560,000 passengers per day by 2016.

Peak services operate at nine minute intervals on the extension and every 10 minutes at other times.

The opening of the extension takes the total length of Line One to 34.5km with 28 stations.

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## BRIDGE SUCCEEDS MCGIRR AS BTS CHAIRMAN

**Great Britain** Britain Roger Bridge, tunnelling manager for Balfour Beatty became chairman of the British Tunnelling Society last month. Effective as of the annual general meeting on 15 May, Damian McGirr, chief tunnel engineer at Donaldson Associates, takes the role of immediate past chairman after two years as the head of the learned society.

As is traditional, Bridge has spent the last two years as a member of the Tunnels and Tunnelling Editorial Advisory Board. Speaking to the magazine, he first paid regard to his predecessor, "McGirr has championed the development of ways in which we can increase the funds coming into the society, allowing us to further our activities, he has also been instrumental in the ongoing development of the MSc and the BTS Young Members, and the increasing contact we have with client organisations."

As for challenges still facing the industry, Bridge identified the potential for a dip in site activities as London's Crossrail project draws to a close, leaving the country without an immediate major project to employ tunnelling personnel. "We are at risk of losing the experience and effort put into training and up-skilling that has been gained, with staff and operatives departing the UK to join projects in the Middle East and elsewhere." Bridge also set out several targets for his time as chair. "I hope that we can develop the means so that our corporate members can be called upon to provide advice collectively through the BTS to assist government and clients in the successful development of projects.

"I would like to be in a position where as chairman I can speak effectively as the voice

of the industry and convey its opinions when issues are presented to the British Tunnelling Society. Then I see us having a much greater input into policies and a much greater ability to provide expertise. I hope to further progress the development of the BTS Young Members, especially with the growing ITA Young Members. Finally I hope to see new BTS courses developed as well as working closely with TunnelSkills and TUCA to produce training that meets the requirements of the industry."

McGirr, in his speech at the BTS Annual Dinner, also emphasised the importance of engaging with clients, and made mention of the work done directly with the High Speed Two rail project as a significant move forward for the BTS. "We can do more," McGirr added. "Not just for the projects, but in terms of utilising underground space to solve major issues such as the recent floods. We should be looking at this, and delivering the message to those who matter.

"It is often easy to get caught up in the infrastructure debate and the pipeline of work. This of course is vital and the BTS should be involved. However, we must also not forget that BTS is a learned society and has a responsibility to develop the art and science of tunnelling and underground space.

"One of the main tenants of our society has been the development of guidance documents, best practice guides and specifications that are internationally recognised and used worldwide. Finally it is key to work towards a joined, co-ordinated relationship between all parties: clients, industry, and international bodies to ensure a consistent standard for tunnels in design and construction."

### BTS bursary deadline passes

**Great Britain** The deadline for applications for the BTS bursary was passed at 5pm on 6 June. The annual grant for a student aiming to take the University of Warwick's Tunnelling and Underground Space MSc stands at GBP 12,000 for the year 2014/15. This amount covers the full course fees, with the balance left over to contribute towards living expenses.

Applicants must have complete an application form available on the BTS website ([www.britishtunnelling.org](http://www.britishtunnelling.org)).

uk) and then send it to the BTS Secretary, either by email at [bts@britishtunnelling.org](mailto:bts@britishtunnelling.org) or by post care of the Institution of Civil Engineers, One Great George St, London SW1P 3AA.

To be eligible candidates must have applied to and been accepted on the MSc in Tunnelling and Underground Space at the University of Warwick, beginning in October 2014; they must hold a relevant engineering, geology or mining based degree from a recognised institution; they must be a UK resident at the time of application and have the

right to remain in the UK for the duration of the course and they must not be in receipt of a bursary or award from another source.

The BTS is looking to develop more engineers with tunnelling knowledge and is looking for students who are committed to tunnelling and who have the potential to excel as tunnel engineers. Desired qualities are: academic ability; a demonstrable interest in tunnelling; leadership potential; aptitude for teamwork; ambition and initiative.

After the application

deadline, all completed applications were due to be assessed by the BTS Committee, which will then shortlist a number of applicants to attend an interview.

All applicants will be contacted via email by 27 June to inform them if they have been invited to the interview day. The decision will be final and feedback to individuals who are not selected for interview will not be given. The interview day will be held in July either in London or at the University of Warwick. Each applicant will have an interview with representatives from the BTS Committee.

### BTS design and construction course

**Great Britain** The BTS Tunnel Design and Construction Course 2014 launches on 30 June. Aimed at young consulting engineers early in their careers, as well in part at client representatives and interested insurance/financial parties, the annual event will this year be held at Warwick University over five days.

Each day has a particular focus: project development, soft ground tunnelling, sprayed concrete lining, soft ground tunnelling (part two), and hard ground tunnelling. Upon completion, the BTS said delegates will understand current best practice in all aspects of tunnel construction from planning through to construction; be informed on risk, technical solutions for differing ground conditions, and the health and safety aspects of tunnelling projects; have networked with other delegates and had the opportunity to discuss technical matters with many of Europe's leading tunnelling practitioners; receive copies of the latest relevant BTS publications. Online booking was due to be open as Tunnels went to press. Prices are GBP 1,150 to GBP 1,475.

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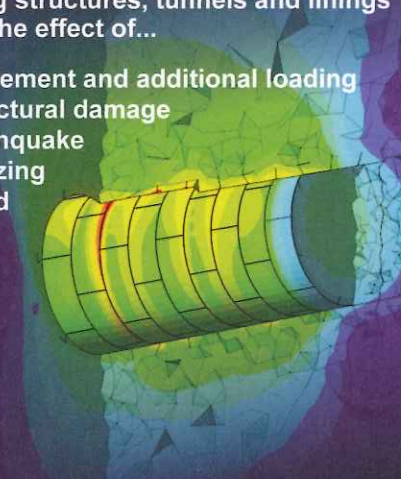
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**Hong Kong's MTR director retires**

Hong Kong TC Chew will be retiring on 28 October from his position as projects director, Hong Kong's MTR Corporation announced. "I would like to thank TC for his dedicated contribution and commitment to the corporation, championing various initiatives to enhance project quality and delivery," said Jay Walder, CEO of MTR. "TC has assumed a leading role in fostering career development and work safety in the construction industry in Hong Kong." MTR has begun a search for a candidate to fill the projects director position. Chew joined MTR as deputy projects director in May 2009 and took up the role of projects director in early 2010.

**Genbina-Icop to be Malaysia's largest microtunnelling firm**

Malaysia Genbina Sdn Bhd and ICOP SpA, a civil contracting company from Italy, on 14 May signed a JV agreement to form a company, the National News Agency of Malaysia reported. Genbina said with the JV, it is now set to become the largest microtunnelling company in Malaysia with the capability of undertaking sizes from 225 to 3,000mm in diameter. Genbina is a leading company in under pressure technology for for major construction in the water and waste water industry in Malaysia, while ICOP is a civil contracting firm involved in the design and construction of tunnelling, deep foundation and soil consolidation, and railway civil engineering work. In a statement, Genbina said the JV company is now able to undertake all major special infrastructure work under the Greater Kuala Lumpur Sewage Plan, Klang Valley Mass Rapid Transit

2, Light Rail Transit 2 and all other civil infrastructure works in Malaysia. "With this strategic partnership, we are confident of securing an orderbook of a minimum of MYR 500M (USD 155M) in the next six months for the year 2014/2015 from the infrastructure sector," said Genbina CEO Aldric Loong Kim Yew.

**Jakarta looking at private investors to finance second MRT line**

Indonesia The Jakarta city administration is considering a PPP to finance the second line of the mass rapid transit (MRT) connecting the capital's east and west. Such an arrangement would deviate from the current funding model, in which a foreign loan, provided by the Japan International Cooperation Agency (JICA), is financing the construction of the first MRT line connecting Lebak Bulus in South Jakarta and the Hotel Indonesia traffic circle in Central Jakarta. "The difference [between the first and second lines] will be in the financing arrangement. We don't want to use a foreign loan to finance the east-west line. We aim to find private investors in a PPP arrangement with [city-owned MRT operator] PT MRT Jakarta at the helm," deputy governor Basuki "Ahok" Tjahaja Purnama said. Studies on the second line are underway, with the city administration and the central government teaming up to lead the process. Ahok said the city aims to break ground on the second line sometime next year. PT MRT Jakarta president director Dono Boestami said there are a number of private investors that have expressed interest in working with the company to build the second line. "We are open to working together with any investors so long as the cooperation will benefit the

city administration and that we get the lowest bid." The complete MRT Jakarta project will cover 110.8km and consist of two main lines: a north-south line (23.8km) and an east-west line (87km). The north-south line will stretch from Lebak Bulus to Kampung Bandan, and be built in two stages. Phase 1 will build more than 15.7km of railway passing through 13 stations (six underground). Phase 2 will expand the north-south line with 8.1km of railway (seven underground stations and one ground-level station).

**Mandalay Resources to acquire Elgin Mining**

Canada Mandalay Resources Corporation and Elgin Mining Inc. announced earlier this month that they have entered into an arrangement agreement pursuant to which Mandalay will acquire all of the outstanding common shares of Elgin for consideration consisting of CAD 0.37 (USD 0.34) cash or 0.4111 of a Mandalay common share per Elgin common share, subject to pro ration. The total transaction value is approximately CAD 70M (USD 64.2M). The transaction will add Elgin's Björkdal gold mine in Sweden as Mandalay's third producing and positive cash flow generating asset. Björkdal is a safe, highly productive, mechanised underground and open pit mine with a highly automated processing plant producing gravity gold concentrate and flotation gold concentrate. Elgin's full-year production guidance for Björkdal in 2014 is 44,000 to 49,000 ounces of gold at USD 886 to USD 982/oz cash cost and USD 1,088 to USD 1,207/oz all-in cost. With Björkdal's forecast production for the second half of 2014 added to Mandalay's existing production guidance, Mandalay's total gold equivalent production

guidance for 2014 increases to 152,000 to 167,000 gold equivalent ounces. Brad Mills, CEO of Mandalay, commented, "Mandalay's core strategy is to acquire cash flowing or near cash flowing assets in geopolitically stable and mining-supportive jurisdictions that have excellent exploration potential and where Mandalay's operational expertise can make a material difference to the performance of the asset in the short to medium-term. The Björkdal mine is an ideal fit for Mandalay. Elgin has already identified and initiated optimization strategies for Björkdal mine. "These, coupled with Mandalay's mine design and execution experience, will insure the operational strategies being deployed at Björkdal achieve maximum impact. "We believe that the application of Mandalay's financial and technical resources can help the Björkdal mine significantly grow production and materially reduce costs per ounce in the coming 12 to 36 months. We expect that with this growth, this transaction will be highly accretive to Mandalay shareholders on an EBITDA, earnings per share, net asset value, free cash flow per share, and reserves and resources per share basis from 2015 onwards at current metal prices." Patrick Downey, CEO of Elgin stated, "The combination of Mandalay and Elgin will provide our shareholders with the opportunity to gain exposure to a growing and profitable producer with operations in politically and fiscally stable jurisdictions, while still providing exposure to the upside at Björkdal. Mandalay has an excellent track record of growing and optimising mine operations and producing value for their shareholders."

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# ITA YOUNG MEMBERS GROUP LAUNCHED

*WTC 2014 in Brazil saw the launch of the new group, which already enjoys a lot of interest from the industry's younger members*

**T**HE ITA General Assembly in Brazil unanimously approved the creation of the ITA Young Members Group (ITAYM) to applause on 14 May. This decision followed on from a social for young engineers on 12 May, and a seminar held earlier on 14 May to set out the mechanics of the group and answer any questions.

Following acceptance at the General Assembly, the group stated its next aim would be to have its own assembly at WTC 2015 in Dubrovnik, Croatia. Committee positions will also need to be filled by elected members, although for the next year, there is a steering board headed by Jurij Karlovšek (University of Queensland) based in Australia, and supported by Petr Salak (Dr. Sauer & Partners) based in the UK.

The ITAYM Group aims to "bridge the generation gap and provide a technical network platform for young professionals in the tunnelling and underground space industry". And the initiative was clearly



Above: Foz do Iguaçu's popular Capitaó Bar hosted the social

well received, with over 65 confirmed attendees at the social. The seminar also attracted representatives from around the world, including: Hungary, Greece, Brazil, Britain, Canada, Austria, South Korea, Germany and Colombia.

This interest, and creation of the ITAYM, is the culmination of over a year of planning and campaign work, begun in January 2013 by Salak, who at that time chaired the British Tunnelling Society Young Members. The success of the group in Britain had led to the move to contact other such national YM groups, and to inspire their creation in countries that had not yet made this step. At WTC 2013, following a presentation from Salak and former BTS chair Damian McGirr, the efforts culminated in the formation of an ITA Task Force, and an unofficial ITAYM group. While newly elected ITA president Soren Eskesen called on ITA member nations to form their own YM groups, or to make existing groups known.

The ITAYM Group is now seeking nominated representatives under the age of 35 from national Young Members organisations. General participation is open to individual affiliate ITA members under 35 years of age who have an interest in the aims of the group. To get in touch, contact [itaym@ita-aites.org](mailto:itaym@ita-aites.org).

"Everything is happening really fast," said Karlovšek at WTC 2014, "it's encouraging and exciting. Nearly everything that exists for the ITAYM has been going for less than a year. We need to be a voice for young engineers in the ITA so that we can create opportunities for the next generation."

One immediate objective is practical preparation for a 2015 ITAYM general assembly in Croatia. There is also work to negotiate lower delegate fees for young engineers, to get a more balanced demographic at future Congresses.

At the conclusion of the ITAYM seminar, Danish representative Lasse Vester offered to buy a beer at WTC 2015 for everyone who creates a national YM group. As vice chair Salak pointed out, this could be an expensive promise.

Alex Conacher

## ITAYM steering board for 2014/15

**Chair:** Jurij Karlovšek (Australia)  
**Vice-chair:** Petr Salak (United Kingdom)  
**Treasurer:** Lasse Vester (Denmark)  
**Secretary:** Nichole Boulton (Canada)  
**Communications and marketing officer:** Sindre Log (Norway)

## ITAYM objectives

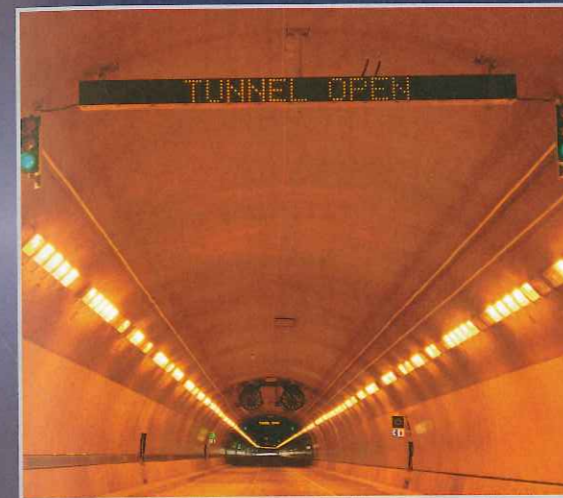
### Primary

■ Provide a technical network platform for young professionals in the tunnelling and underground space industry

### Secondary

- Provide international information hubs for young professionals in order to exchange experience and to build the professional network
- Outline the need to bridge the gap between generations and embrace the opportunity to network across generations in the industry
- Improve awareness of the tunnelling and underground space industry in new generations

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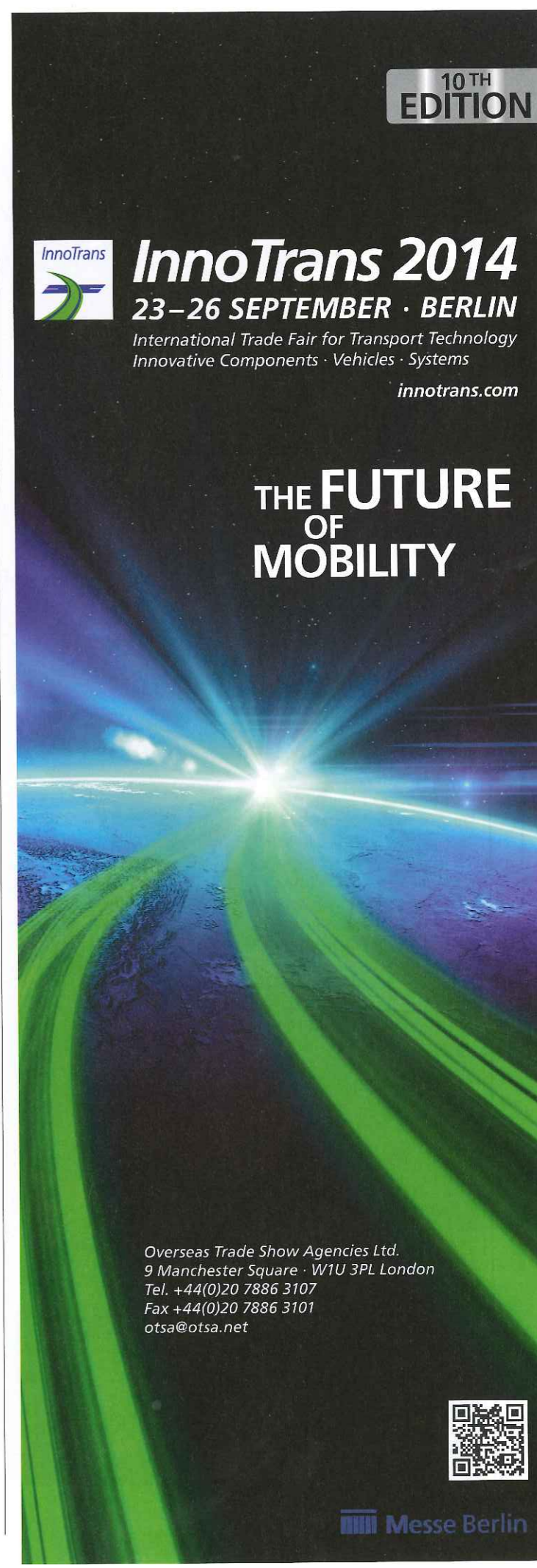
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## HIGH MPA SLOG

Southland Contracting has reached daylight on the Corbalis to Fox Mill water main project in Fairfax, Virginia, USA. On 8 May, a 2.2m-diameter Robbins Double Shield TBM broke through, completing 2.7km of hard rock tunneling that the manufacturer described as a test of endurance. Diabese rock encountered exceeded 345MPa UCS and had already prevented an earlier contractor's attempt at the bore.

John Marcantoni, project manager at Southland Contracting said, "The rock that we encountered was greater than 50,000 psi in many places. From start to finish, it took about 1.5 years to go 1,890m." When Southland was awarded the work, they first had to remove the trapped TBM at the 730m mark.

Marcantoni added, "Our issue was not water inflows, faults, or seams, it was actually the consistently hard rock. The machine was working at its highest capacity just to cut the rock. We kept pushing—a lot of our success was in maintaining the cutters and the ability to keep pushing as hard as we could. We had a rigorous maintenance schedule."

A spokesperson for manufacturer Robbins stated, "The strength of the rock not only tested the equipment, but also generated a lot of heat, making working conditions and cooling the equipment difficult. Despite the equipment challenges and much higher than normal cutter wear, the machine continued to push forward."

"The TBM was originally built in 1999 for a Cleveland, Ohio sewer tunnel, the Corbalis to Fox Mill Water Main is the machine's seventh project. After extensive research on the record, the only similar project found in North America was excavated by a 2.1 m Robbins Double Shield in Montreal, Quebec, Canada. Bored in 1998, the St. Jerome Tunnel was excavated through rock at maximum strengths of 294 MPa (42,600 psi) UCS."

The 2.68 km tunnel is part of a larger 3.44 km (2.14 mi) scheme, approximately 762m of which was open cut. The remainder of the tunnel required a TBM due to its depth and close proximity to highways, buildings, and other structures. Drill and blast was prohibited due to the presence of two active petroleum lines running parallel to the tunnel and providing service to nearby Dulles Airport.

## DATA LOSS

Dear Sir,  
I was delighted to see the paper in the May issue of T+T. However, on second sight I have the following remarks:

The printed paper ends abruptly on page 65 in the middle of the last sentence of the chapter "suggestions for tunnelling practice". The acknowledgments and the reference list are missing, which is very unfortunate.

Markus Thewes  
Chair for tunnelling and construction management  
Ruhr University Bochum

### IN RESPONSE...

Due to a printing error, the end of this paper and several important elements were missed. Tunnels and Tunnelling would like to apologise, and we have reprinted the information in question. You can find it on p.58.

Editor

### A mountain of Uttarakhand disaster responses

Mahendra Bisaria's article on the Uttarakhand Disaster (Tunnels February 2014, pp.28-33) seems to have struck a chord, judging by the myriad of responses. Several are printed here:

The article is well drafted and has enumerated significant related points. The calamity is a natural phenomenon, it is unprecedented and extremely shocking. I am of the view that there are some factors, which require taking care of. About two years back, I, while travelling from Tehri to Uttarkashi noticed that half of the road had been washed away, at numerous places, during earlier floods, thus depositing the muck in the bed of Bhagirathi, thereby reducing the capacity of the river. Numerous landslides had also developed and old ones triggered, which could have contributed to the deposition of muck in the river, as also snapping the road communication, leaving the Tourists isolated and helpless. Similarly along the road to Badrinath numerous landslides had developed which block the road during and after monsoon every

year. The above feature may not be taken against the construction of roads. The need is to adequately protect the slides, if it is active slide, alternative road or tunnel may be constructed to bypass the slide, as has been done for the Nashri slide in Jammu Region. There are numerous examples of short communication tunnels also.

With regards to the muck disposal, sites are selected keeping in view the topography and Ecology and marked on the plan which is appended with the Detailed Project Report (D.P.R.), and is submitted for the approval of C.W.C and C.E.A. The Project also contributes significantly to the development of the Catchment Area (C.A.T. Plan).

There is a feeling against the Construction of Hydroelectric Projects. If the Projects are dropped, we shall be facing acute power shortage. Two major projects in Uttarakhand have already been dropped, these are, Bhaironghati (Preconstruction stage) and Pala Maneri (construction stage). It can be concluded that the devastating floods, of last year, were not caused by construction projects.

H.M. Dayal  
Director of engineering  
(retired)

I am browsing and reading the Tunnels and Tunnelling Magazine for the past ten to fifteen years and glad to read the Views of M.S.Bisaria, Management Consultant of Gammon Infrastructure on this issue. The presentation of the article on disaster in Uttaranchal and Hydro Power Development - a view that is encouraging the reader. The article covers the past disasters and remedial measures under taken in Himalayan Region raises curtain on certain myths about the hydropower Development. The views expressed in the article would be guiding for prosperous and safe development of much needed hydropower in the country, which is opened up for the PPP.

J.D Patel  
Gammon Infrastructure

After the Uttarakhand disaster; many agencies, NGO's visited the affected area and in the name of environment & development, they were blamed on hydro power projects. Local/general public don't know about rules, approvals, investigation part, construction activities involve in hydro power project and its benefits.

The paper clearly explains the relationship between clean development & natural disasters in Himalaya, modern technologies taken/implemented by project developer companies, Socio-economic effect on project area & previous natural disaster in Himalaya and how Indian government water policy (construct dam, landslide protection etc) minimise the losses caused by it and Bisaria's experience gives a practical explanation.

Last but not least, the paper gives new way of thinking about development & environment. In my view, this paper is best among all the previous published articles on Uttarakhand Disaster.

Vinay Kumar Pande  
Gammon Infrastructure

The author has presented several thought-provoking aspects of the construction practices for hydroelectric projects, in the context of the recent flood-related disaster (in the disaster-prone region of Uttarakhand, India).

I am somewhat familiar with the pre-1970 state of planning and investigation of some hydroelectric projects and dams in India and some recent projects in some developing countries and developed countries. The author's comments about earlier projects in the Himalayan region having been constructed 'in complete disregard of the health of the river' and PAP concerns point to the inadequacy of the environmental and feasibility studies for such projects.

His suggestion about muck disposal so as not to 'foul the environment' and 'interfere with the natural drainage' indicates that this has not been analysed during environmental investigation. An environmental report must compare all pro-construction alternatives with a no-project option. This may be particularly significant because for many projects in India the government or its autonomous entities may be the sponsor, financier, construction manager, and also the regulator. Sometimes, even the main financial beneficiary is the government. This may introduce pro-project bias in decision making.

Delay in approvals of project construction merits criticism, but adequacy and thoroughness of environmental and feasibility studies must not be reduced just to expedite approvals.

The 'act of God' argument is strong for the disaster. However, the damages may have been due to human inaction. If proper protective measures had been implemented, perhaps the damages could have been minimised.

Anand Prakash, Ph.D

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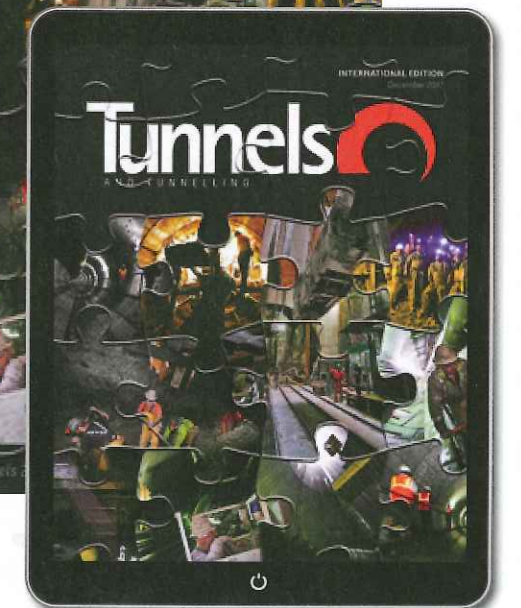
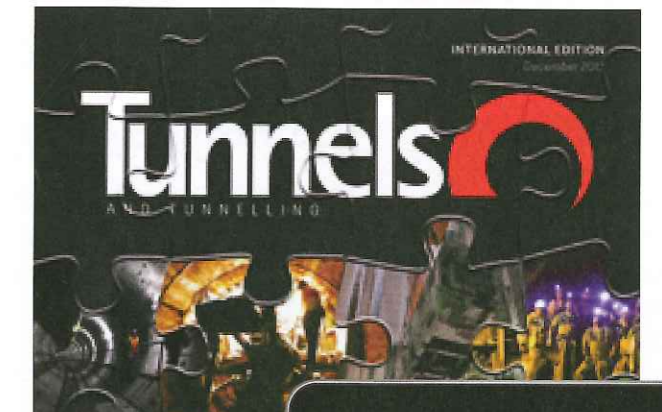
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# SUBSEA SELECTION

Construction of the Ryfast subsea road tunnel is underway, and Norway plans more strait crossings. Report by **Patrick Reynolds**

**F**OR THE last few decades, Norway has been striving to better knit together key stretches of the road network that hugs its fjords on the west coast. The strategic vision is to save time and boost regional economies, and to that end a variety of construction methods have been employed to cross the straits, such as bridges and subsea tunnels – the latest of which is the Ryfast scheme under construction near Stavanger. ▶

*Patrick Reynolds*

Patrick is a freelance technical journalist who has covered tunnelling projects worldwide and has a mining background



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Above: Location of Ryfast, Eiganes and Rogfast schemes, in Norway

The Ryfast link will be 19.5km long, built almost entirely underground, and will establish the Rv13 road as an all-weather link between Stavanger and Ryfylke region to the east. The fixed link will replace the current ferry connection.

Ryfast comprises two tunnels: Hundvåg Tunnel, which will weave out from under central Stavanger to surface at Hundvåg island; and, Ryfylke Tunnel, running on from the island for about triple the distance and depth below sea level of Hundvåg Tunnel, to emerge at Solbakk near Tau, in Rogaland county.

Yet, for all its size, Ryfast is only a branch off the west coast's main trunk road – the E39. They will be connect at another new tunnel – Eiganes Tunnel – a shorter, new land-only link sits on the main highway.

The national roads authority, Vegvesen, is constructing the three tunnels as part of the same scheme, which was approved by the Norwegian Parliament in 2012, and is to open to traffic by 2019.

In addition to improving regional links, the scheme will also help reduce traffic congestion in Stavanger, says Ryfast-Eiganes project manager, Gunnar Eiterjord.

Subsea road tunnels have been a key feature of the transport improvements made along the E39 from Kristiansand to Trondheim, and more are planned, says the route's project manager, Olav Egil Ellevset.

One large project is well ahead in planning – the 25.5km long Rogfast scheme, which would be Vegvesen's longest subsea road tunnel.

If parliamentary approval were to be received this year, construction might start around 2015, the roads authority proposes.

If so, then the overlapping construction schedules of Ryfast and Rogfast could mean Stavanger becomes an even greater tunnelling hotspot later this decade.

### RYFAST AND EIGANES TUNNELS

Consisting of the Ryfylke and Hundvåg tunnels, which are 14.3km and 5.5km long, respectively, the NOK 6.2bn (US 1bn) Ryfast strait crossing is a twin tube link in both sections. There the similarity ends, for the longer of the two is the narrower, and will take less than half of the traffic, but will go much deeper.

Ryfast's geology comprises gneiss and phyllite, and Eiterjord notes that small leaks were experienced when tunnelling through phyllite in a previous scheme, Rennfast, which included the Mastra Fjord tunnel near Stavanger.

There is also phyllite in the Stavanger area of the 3.7km-long Eiganes Tunnel, which is budgeted at NOK 2.5bn (USD 405M). While Eiganes is far shorter than Ryfast overall, and being constructed totally on the mainland, it is budgeted to be just over double the cost per kilometre.

Eiganes is much more of an urban route than the Ryfast tunnels, and its challenges include: the built environment; underground ramps and connections to the existing road network; the highest forecast traffic volumes of all the tunnels; and, therefore, it has large twin tubes of the same size as Hundvåg. Eiterjord notes that parts of the route have only 15m to 25m cover.

The balance of Eiganes' project finance structure is also notably different to Ryfast's: the state will fund 49 per cent of Eiganes; but Ryfast only gets 14 per cent from central government plus 6 per cent from local government, the city and business. The balance of funding for both projects is to be paid through road toll charges – and so would make Ryfast the most expensive road link for road users in Norway, notes Vegvesen.

The main consultant of the scheme is Norconsult.

#### Ryfylke Tunnel

Ryfylke Tunnel is the main strait crossing link on Ryfast, and stretches from Hundvåg to Solbakk, passing below the island of Hidle on the way. Until recently, it was called Solbakk Tunnel.

Two contract packages have been awarded for construction of Ryfylke Tunnel, and Hidle island marks the boundary between them – Contracts E02 and E03, which are 7.6km and 6.7km long, respectively, says Eiterjord. The tunnel is 290m below sea level at its deepest point, on Contract E02.

A JV of Swiss contractor Marti and its Icelandic subsidiary IAV was awarded



Above: Preparing to blast at Solbakk for Ryfylke Tunnel

Below: Layout and lots on Ryfylke, Hundvåg and Eiganes tunnels

Contract E02 tunnel and portal works in April 2013. Tunnelling on the NOK 1.3bn (USD 218.5M [excluding VAT]) contract began the following August.

Twin drives are being blasted from the Solbakk portal, driving westwards. By the beginning of 2014 the faces had each advanced approximately 500m, says Anne-Merete Gilje, Vegvesen's project manager for Ryfast. From Solbakk, the tunnels will descend at inclines of 7.2 per cent to the lowest point of the link, below Hidle fjord, and from their will rise

at 1.3 per cent grade towards the island.

The Contract E03 works will construct the Hidle to Hundvåg section of Ryfylke Tunnel, plus a small part of neighbouring Hundvåg Tunnel. Vegvesen signed the Nkr 1.17bn (USD 196.6M [excl VAT]) contract with local firm AF Gruppen in July 2013, and the drill and blast drives were about to get underway in January, advancing eastwards from the Hundvåg portals. The vertical alignment has grades of 7.9 per cent and then easing to 2.7 per cent below Horge fjord towards Hidle, to meet the E02 drives.

Upon completion, Ryfylke twin tubes will have horseshoe-shaped, T8.5 finished profiles (8.5m wide at road level, and 4.6m clearance), each with two lanes for traffic. The tubes are to be connected every 250m by emergency access tunnels. Opposite every second exit will be a widened area for vehicles to stop.

Forecast traffic levels at the opening are 4,000 vehicles/day, doubling by 2035. Below Hilde, the tunnel will be locally widened and have soft feature lighting on the walls to break up the monotony of the long journeys for drivers, says Vegvesen.

#### Hundvåg Tunnel

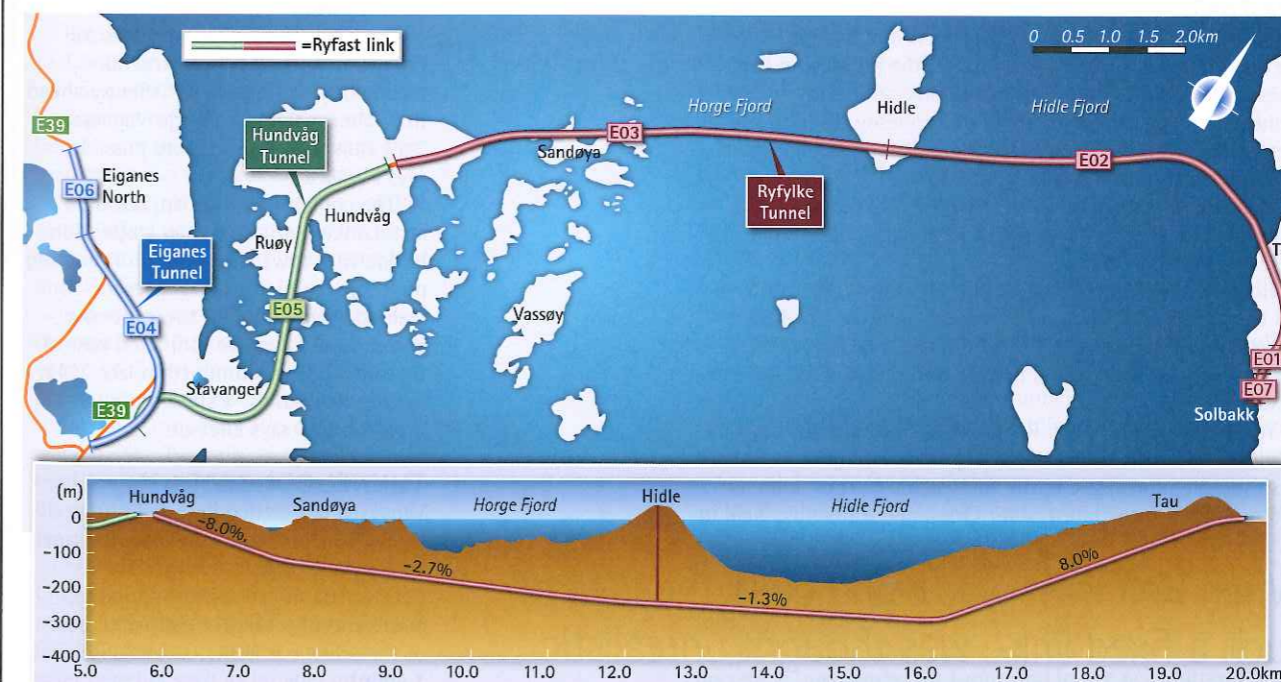
Traffic coming from Solbakk will emerge from Ryfylke Tunnel onto a short open stretch of road on Hundvåg island, next to Stavanger, and then quickly enter 5.5km-long Hundvåg Tunnel to complete the journey into the city.

Under Contract E03, AF Gruppen is also to construct the Hundvåg Tunnel's portals as well as those for its main contract. However, the majority of Hundvåg Tunnel – almost, but not quite reaching E39 Eiganes Tunnel – is to be built in Contract E05, which was due to be awarded in late January, says Gilje.

Hundvåg Tunnel's twin tubes will be constructed with T9.5 finished profiles (9.5m wide at road level, and 4.6m clearance), include access ramp tunnels near Buøy on the island, and descend to 95m below sea level. It will come out next to Gamlingen junction in the city, near the south end of E39 Eiganes Tunnel.

Like Eiganes Tunnel, among its design and construction challenges is the urban setting and, hence, sections with low overburden, notes Gilje.

Traffic levels in Hundvåg Tunnel are forecast at 10,000





vehicles/day initially, rising to vehicles/day after 16 years. The tunnel will relieve traffic on City Bridge, which links the island to Stavanger.

#### Eiganes Tunnel

Eiganes Tunnel will run from Tasta, at the northwest edge of the city, to just south of Gamlingen. It is to be mostly constructed under Contract E04, the bid deadline for which was mid-December 2013. Eiterjord says it will be the largest and most diverse contract on the entire scheme. Excavation is expected to start this Spring, adds Gilje.

Part of the works package also include, at Gamlingen, the south end of Hundvåg Tunnel, including the portals and short sections of tubes.

Eiganes Tunnel's own twin tubes are the same size as those of Hundvåg Tunnel, but the volumes of traffic are forecast to be much higher – 20,000 vehicles/day at opening, rising to 35,000 vehicles/day by 2035.

#### ROGFAST

Currently, the E39 highway is bottlenecked at Stavanger. After the congestion of traversing city roads, the journey onwards takes vehicles via a series of small islands, and short subsea tunnels, to reach the larger island of Rennesøy. Then, from there, a ferry shuttles from Mortavika across the Bokna fjord to Arsvågen, on the island of Vestre Bokn.

The subsea road tunnels are Mastra Fjord and Byr Fjord, which are the two key parts of the Rennfast scheme built in the early 1990s.

However, if Vegvesen's latest plans go ahead, the route will be quieter after 2022, and the ferry gone, as the E39 is being re-routed to stretch north from closer to Stavanger. The colossal Rogfast fixed link is to take traffic across the fjord to Arsvågen.

Yet, in the 1990s, when Rennfast was being built, the idea of such a fixed link over such a deep and wide fjord as Bokna was thought "unrealistic in the foreseeable future," Ellevset told delegates at the latest Strait Crossings conference, held in

**When Rennfast was being built, the idea of such a fixed link... was thought unrealistic**

*Above: Ryfylke Tunnel is part Stavanger's Ryfast strait crossing*

*Opposite: Shotcreting in one of twin drives from Solbakk*

Bergen last year.

But ongoing studies, drawing upon technological advances in tunnelling, brought a plan for a world record-breaking length of subsea road tunnel.

And, at its deepest, the Rogfast tunnel would be 380m to 400m below sea level, even though the fjord goes much deeper. The feasibility design has been able to take advantage of the seabed profile created when the fjord was floor was carved in the Ice Age; there is a curved sill at the mouth of the fjord, and the tunnel alignment traces that path.

Usually, a subsea road tunnel has to compete against a bridge option to form a strait crossing on the Norwegian west coast. Not so at Bokna fjord – that is, until relatively recently.

Again, technological advances for bridges were the key. Construction technology had moved sufficiently ahead that, almost three years ago Vegvesen "saw that such bridges were possible," says Ellevset.

The competition was on, but didn't last. Looking at a five-span suspension bridge with towers supported on floating pontoons, or platforms, Vegvesen realised it would be far too expensive – about three times the estimated cost of the tunnel. It was dropped in late 2012, leaving Rogfast as "a subsea tunnel project only," says Ellevset.

#### TUNNEL CONCEPT

Vegvesen has settled on a twin tube tunnel concept, linked by cross passages, for Rogfast, project manager Tor Geir Espedal told the Strait Crossings conference. He said the estimated cost of the scheme is NOK 10.2bn (USD 1.64bn).

The tunnel route runs from near Harestad, in Randaberg, northwest of Stavanger, and passes below the fjord – passing the island of Kvitsøy – to surface near Arsvågen.

Geology along the alignment is complex. It is understood to comprise phyllite and mica schist near the Randaberg end but then, depending on the throw of the fault zone, may enter the Karmøy Ophiolite (gabbroic gneisses, hypabyssal rock types, volcanic rocks, sediments and dark, quartz-free ultramafic rock types) or Storheia Nappe (granitic and dioritic gneisses), or go right down to phyllite. However, further faults could lead to more variations in what may be met before the tunnel is in phyllite again at the Arsvågen end.

Onshore and offshore surveys are currently underway to supplement data already compiled by consultants Sintef and Cowi.

The deepest point of the tunnel alignment is about midway between Kvitsøy and Arsvågen – in the faulted area with the least known geology. From there, the maximum slope is proposed to be seven per cent over a 3km-long section up to Arsvågen, and an additional climbing lane for vehicles might be included. But Espedal says design development, instead, might see the grade reduced to five per cent and the section made up to 1.5km longer.

Passing near Kvitsøy, the scheme will have a 4km-long access tunnel branching off to the island as a single tube from the main tunnels via a two-level interchange. The branch tunnel would house fire doors to protect the main tunnels.

Cross passages are planned at 1,250 to 1,500m centres for emergency vehicles, and for all vehicles every 4km. Emergency exits for passengers are to be no more than 125m apart when the gradient is five per cent or more.

Longitudinal ventilation is to use the piston effect of traffic moving the air mass, but airflow would be boosted by impulse fans.

Espedal says the Rogfast tunnels – planned as T10.5 cross-sections (10.5m wide at finished floor level) – might be bored rather than blasted following a tunnelling study that also considered using TBMs. Typically, Norwegian subsea road tunnels are excavated by drill and blast, and the method was looked in a feasibility study by Cowi and Sintef.

Sintef's Eivind Grøv briefed the Strait Crossings conference on the study, particularly the possibilities for TBMs. Shield bores are considered able to offer benefits such as broadly greater



**400**

Metres below sea level could possibly be the deepest point of the Rogfast tunnel.

**19.5**

The length in kilometres of the Ryfast project's tunnels

tunnelling speed, reduced grouting, and lower excavation risks in weaker geological zones, but the method is estimated to be more expensive.

The study looked at boring 12.2m o.d. twin tubes by TBM, or a possibly a single, 19.6m o.d. tunnel. Various scenarios were examined with different numbers of TBMs to suit tunnelling sequences, risks and logistics.

It was concluded that tunnelling risk could be reduced by delaying cross passage construction until the main tunnels were finished.

Project funding for Rogfast is mostly based on tolls, similar to Ryfast. Traffic levels are forecast at 6,000 vehicles/day at opening, rising to 13,000 vehicles/day over 20 years, after which the tolls stop.

#### FUTURE: TUNNELS AND TOLLS

Aside from Rogfast, the next subsea tunnel contending for a spot on E39 is at the Vestnes-Otrøya strait crossing, one of two fixed links on the Møreaksen scheme to connect Molde and Alesund, in mid-Norway.

A final decision on whether the 15.5km long tunnel will proceed as the favoured option is expected this year, says Ellevset. The tunnel would be 330m below sea level at its deepest point.

At Halså fjord, a subsea tunnel was previously the main option for a fixed link. Two tunnel alternatives were considered with lengths of 12km and 16km, respectively. But a suspension or floating bridge "has become more likely now," says Ellevset. "So, for the E39 project," he says, "bridges will be the main focus for most of the remaining crossings due to the depths" at the fjords.

However, as noted at the Strait Crossings conference, other construction technologies are being explored, such as anchor-weighted or floating submerged tunnels for either full fjord crossings or as part of hybrid fixed link structures. Such ideas have been examined in feasibility studies to cross Sogne fjord, a tourist magnet for cruise ships.

While plans are made, however, there are fresh uncertainties surrounding the toll regime in future, following a change of government at the national election, in autumn 2013.

"We expect some change in the policies related to road tolls," says Ellevset.

What certainty there is, though, is that Stavanger will become a busy centre for tunnelling in the near future

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## STOCKHOLM PREPARES FOR TUNNELLING BOOM

*Bernadette Ballantyne*

Bernadette is a regular contributor to *Tunnels*  
and editor of *Underground Utilities*



**T**AKING THE Slagsta car ferry from the island of Lovön over to the mainland is a pleasant, if not bracing experience. The wind is biting and the rain persistent but this is February in Stockholm. Two hours previously it had been snowing. The bright yellow car ferry is one of a handful of small scale links between the islands that make up the city, which has surprisingly limited accessibility for a capital of such importance. "The Saltsjö-

Sweden's capital city is going underground to improve transport connections to Stockholm meaning that a tunnelling boom is on its way in this part of Scandinavia. **Bernadette Ballantyne reports**



[www.tunnelonline.info](http://www.tunnelonline.info)

Mälarsnittet effectively cuts the city into two pieces," explains Johan Brantmark, project director at the Swedish Transport Administration (Trafikverket). "It is difficult to live on the north side and work on the south side because the commuting times are too long. We have one high capacity road crossing - the Essingeleden link but it is hugely congested. Whenever there is any sort of incident it is a nightmare," he says.

To provide much needed resilience to the city, which is growing at the rate of around 40,000 people per annum, Trafikverket will oversee construction of a new highway running from Skärholmen in the south up to Häggvik in the north (see map).

Twin tunnels will host 18km of the link, which will be created using drill and blast through the hard granite bedrock. The total road length is 21km and of the 18km of tunnel 16.5km is a continuous section.

At SEK 28bn (USD 4.2bn) the project will not be cheap but a tunnelled approach was deemed vital to preserve the environmental heritage of the area. The new road runs near a UNESCO World Heritage site - Drottningholm Palace, residence of King Carl Gustav of Sweden, situated on the picturesque Lovön island, in Lake Mälaren.

Running beneath the Lake, and ensuring that the tunnel avoids any potentially fractured rock means that at its deepest point it dives to 60m below ground level.

"It was originally planned as a three lane surface highway," says Brantmark. "Up until some years ago it was a tunnel that came out as a bridge across the straight in the northern part of Lovön, and then as part of the negotiation and planning process that bridge was taken away because of the visual impact that it would have and its intrusion into another natural reserve.

"So that made us decide to put it underground all the way," he explains.

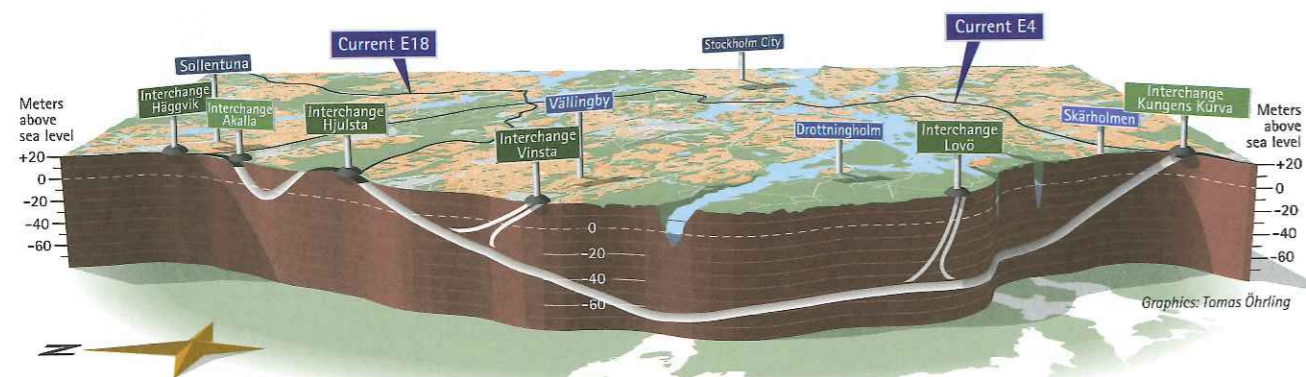


Above: North-south highway project, showing underground portions in red

Below: Profile view of the project, to 70m depth

**NEXT STEPS**

The next major step for the project is the final approval of the land acquisition plans expected in the summer. After this procurement will begin in earnest for some 50 contracts, using a mix of design and build and build only contracts. Contracts for two access tunnels at Skärholmen at the southern end of the link have already gone out to tender and prequalification is underway for two further packages. The biggest contracts to be tendered are the six build only packages for the tunnel and six design and build contracts for the major interchange points. Brantmark expects that in the next two years total value of contracts let will be USD 2.77bn. It is not surprising then that the organisation wants to see more international firms come into Sweden and Trafikverket has been hosting information sessions with contractors overseas. "We believe that the Swedish construction industry has lived life a little bit



Graphics: Tamas Öhrling

Table 1. City Line: Major contracts

Contract	Value (SEK millions)	Contractor	Designer
Söderström tunnel	1,900	JVS, Joint Venture Söderström – Züblin (and previously Pihl & Søn)	Cowi
Stockholm City station and the Norrström tunnel	1,800	NCC	WSP
Stockholm Odenplan station and the Vasatunnel	1,500	Bilfinger	Sweco/Grantmij
Norrmalm tunnel	400	Strabag	WSP
Södermalm tunnel	400	Züblin	Ramböll
Stockholm South station	300	Züblin	Ramböll/ELU
Railway bridge at Årsta	300	Züblin (previously Pihl & Søn)	Cowi/Centerlöf & Holmberg
Tomtebodas concrete tunnel	250	PEAB	Sweco/Grantmij

Source: Client

separate from Europe and from our perspective we see that as a problem. We welcome international competition and we are actively seeking that," says Brantmark.

Construction of the road tunnel will involve excavation of some 19 million tonnes of granite using drill and blast, a choice decided by the good quality rock and the dimensions of the three lane highway that is too wide and short for a TBM bore. "It is a permanently supported blasted tunnel but then we have an inner liner. We are putting in bolts and a 100mm shotcrete structure and PVC liner to make it absolutely watertight," says Brantmark.

Importantly the client is taking on the risk of unexpected ground conditions but Brantmark does expect that the environmental conditions, which are yet to be finalised by the country's environmental court, will put conditions on allowable

Below: Concrete works at the platform area of the Stockholm Odenplan

**4** Million tonnes of rock have needed to be excavated for the rock tunnel

seepage into the tunnels. "We are afraid of too much groundwater drawdown and so the conditions will dictate the allowable seepage. We tackle that with pre grouting and that is a time consuming procedure," says Brantmark, nevertheless it must be priced.

"As the project evolves and we learn more about the job and the ground conditions we might be able to make changes but this is not something that we can guarantee. The price that we are looking for is one that includes this. Hopefully we can make it easier but it is something that needs to be done."





## Supporting the first Metro Line in Panama.

**Panama, Panama City.** Central America's first metro network will be built in Panama City. The largest infrastructure project since the construction of the Panama Canal is scheduled to be completed in 2014, when line 1 will be opened to traffic. It will have a length of 13.7 km and will serve twelve stations. Line 1 will run from the "Albrook Bus Terminal" in the south to the "Los Andes Shopping Mall" in the north, passing through downtown Panama City. During this tunneling project, the challenge for H+E was to guide the tunnel conveyor system safely through the narrow S-curve. Booster stations solved this problem to the utmost satisfaction of our customers and made the project a success.

### Technical data:

- Tunnel diameter: 8.70 m
- Conveyor length: 4,225 m/ 3,398 m
- Belt width: 1,000 mm
- Capacity: 1,200 t/h
- Installed power: 5 x 160 kW  
1 x 90 kW  
4 x 160 kW
- Belt storage capacity: 2 x 600 m
- TBM: EPB
- Installation: 2012



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Of all the tunnelling contracts three are a similar size – those at Skärholmen, Johannelund and Sodra Lovö. Each require the excavation of around 1.5Mm<sup>3</sup> of rock. Further packages at Norra Lovö, Lunda and Akalla also have significant volumes to be removed. Around 50 per cent of this will be taken away via barges from three temporary jetties, a move designed to reduce construction traffic. Trafikverket has already begun negotiating contracts to sell the rock.

"It is large volumes and needs environmental permits so whoever has contract needs to get permissions and it creates a level playing field for all of the contractors," Brantmark says. "Typically in Sweden we would make rock the contractors asset but we believe that could favour some contractors and that will not make it easier for international contractors to enter the country."

On the same theme Brantmark says that the building information model software has been created with a neutral platform so that contractors can use their own preferred systems. This project represents Sweden's first major foray into the use of BIM and Trafikverket have looked to London for inspiration here. "Crossrail have really moved far in this direction and we have been and visited with Crossrail and believe that there is a lot in Crossrail that makes sense."

This is a major challenge for the scheme and represents a step change in how project information is used and stored. "On the design and build we require models back so that we can use them as a basis for procuring E&M works and for the as built documentation. It is very, very different. We have procured using models before on a running cost basis. This time it is a fixed fee basis so there are big requirements on the tender documents which makes these design and build jobs special."

Another key issue for Trafikverket is the quality control (QC) during construction. Brantmark is keen to see a proactive approach from contractors and urges them to appoint senior staff at a high level to the quality control role. "My vision is to have contractors who come on the site with a QC attitude that is so strong that I can start to take my people off the site. On the City Tunnel in Malmö, the contractor had a quality



Above: Projects in the general Stockholm region

manager worth the name. If we saw deficiencies somewhere we could just go to the QC person who had the ear of the director and that was enough."

Construction on the scheme is expected to ramp up in 2016, representing a busy year for contractors in the city as the metro is also set to be extended and a number of other tunnelling works for sewage and electrical cables are also expected. "If everything goes ahead as planned 2016 will be an extremely busy year for contractors, the volume of tunnelling works is increasing every day."

### DOING THE HOMEWORK

For contractors interested in the construction conditions they need look no further than the City Line rail project, which is currently under construction. "This is the number one railway project in Sweden and if we could have done it earlier, we would have," says Kjell-Åke Averstad project manager for the City Line project at Trafikverket. His scheme is a 6km rock tunnel with two new station boxes that is set to double commuter rail capacity through Stockholm city centre. Known locally as the Citybanan project, the scheme will enable high speed rail to run through the city's existing tracks creating better links with the rest of the country.

Earlier iterations of the project considered in the 1990s involving more surface lines were abandoned in favour of tunnels. "Of course tunnelling is more expensive but it is a much better solution," says Averstad.

Planning of the project began in 2000 and construction finally started in 2009. The creation of the rock tunnel has led

If we saw deficiencies somewhere we could just go to the QC person and that was enough

Table 2. Bypass major tunnelling contracts

Contract	Description	Primary rock amount (m <sup>3</sup> )
FSE 209	Main Tunnel, Skärholmen	1,400,000
FSE 210	Access tunnels and temporary harbour, Skärholmen	67,000
FSE 302	Access tunnels, temp harbour and main tunnel, Norra Lovö	1,060,000
FSE 308	Access tunnels, temp harbour and main tunnel, Södra Lovö	1,544,000
FSE 403	Main tunnel, Johannelund	1,500,000
FSE 410	Access tunnels and main tunnel, Lunda	416,000
FSE 607	Access tunnel, Akalla	12,000
FSE 613	Main tunnel, Akalla	400,000

Source: ICD Research Industry Survey 2011

to the excavation of 4Mt of rock and concreting work is advanced with over 70 per cent completed. Construction has been carried out under eight major civil contracts including two contracts for the new station boxes with linked tunnels, four further tunnelling contracts, a connection to the existing station in the south and a new railway bridge.

"They are all very different. We have design and build, build only, and different financial contracts depending on the subjects and what we thought we had in front of us," explains Averstad.

The station box contracts for Stockholm City station and the new Odenplan station with connecting tunnels were carried out under a cost reimbursable arrangement.

"We knew that from the beginning the preliminary design wasn't the final design. We knew that you can optimise the design and work a lot with changing between concrete and rock and so on," he explains.

This meant bringing the contractors, NCC and Bilfinger respectively, in early and working together with client and designer to find solutions that could save time and money. "We put out a target price and if we go under that together we have a bonus system. Bonuses are very effective in this type of contract," says Averstad.

In 2007 the price level for the entire scheme was set at SEK 16.8bn (USD 2.52bn) and allowing for inflation it is today just under SEK 20bn (USD 3bn).

The approach has been a resounding success for Trafikverket. "We have 70 per



Above: Escalator shaft at the Stockholm City station, December 2013  
MIKAEL ULLÉN

cent of the money used so we are on track. The plan is that we will finish one year ahead of the date that we set at the beginning and we are forecast also to go under budget."

This is all the more remarkable considering the complex nature of the project and the challenges encountered along the way. One of which was the financial downfall of Danish contractor Pihl & Søn filed for bankruptcy in mid 2013. The contractor was engaged in two of the eight contract packages, including the largest package for the SEK 1.9bn (USD 280M) Söderström tunnel in joint venture with Germany's Züblin, and the SEK 300M (USD 45M) railway bridge at Årsta.

Fortunately Züblin was able to deliver both contracts without its former partner. "Of course it was a problem but we managed to still do it," says Averstad. "We solved the problems in a way that has had local time delays but not impacted on the overall programme so we have succeeded in meeting the goal timescale."

Lessons from the scheme are all the more important given Sweden's plans for major work.

Averstad credits good communication, strong planning, cooperation and getting stakeholder acceptance early. "From the beginning we had a high level of communication from the project with the surroundings and that was the most important part of the success in keeping the timescale."

"You must have a very competent management team – and some luck"

Lessons from the scheme are all the more important given Sweden's plans for major work



# TUNNELLING AND MINING EQUIPMENT

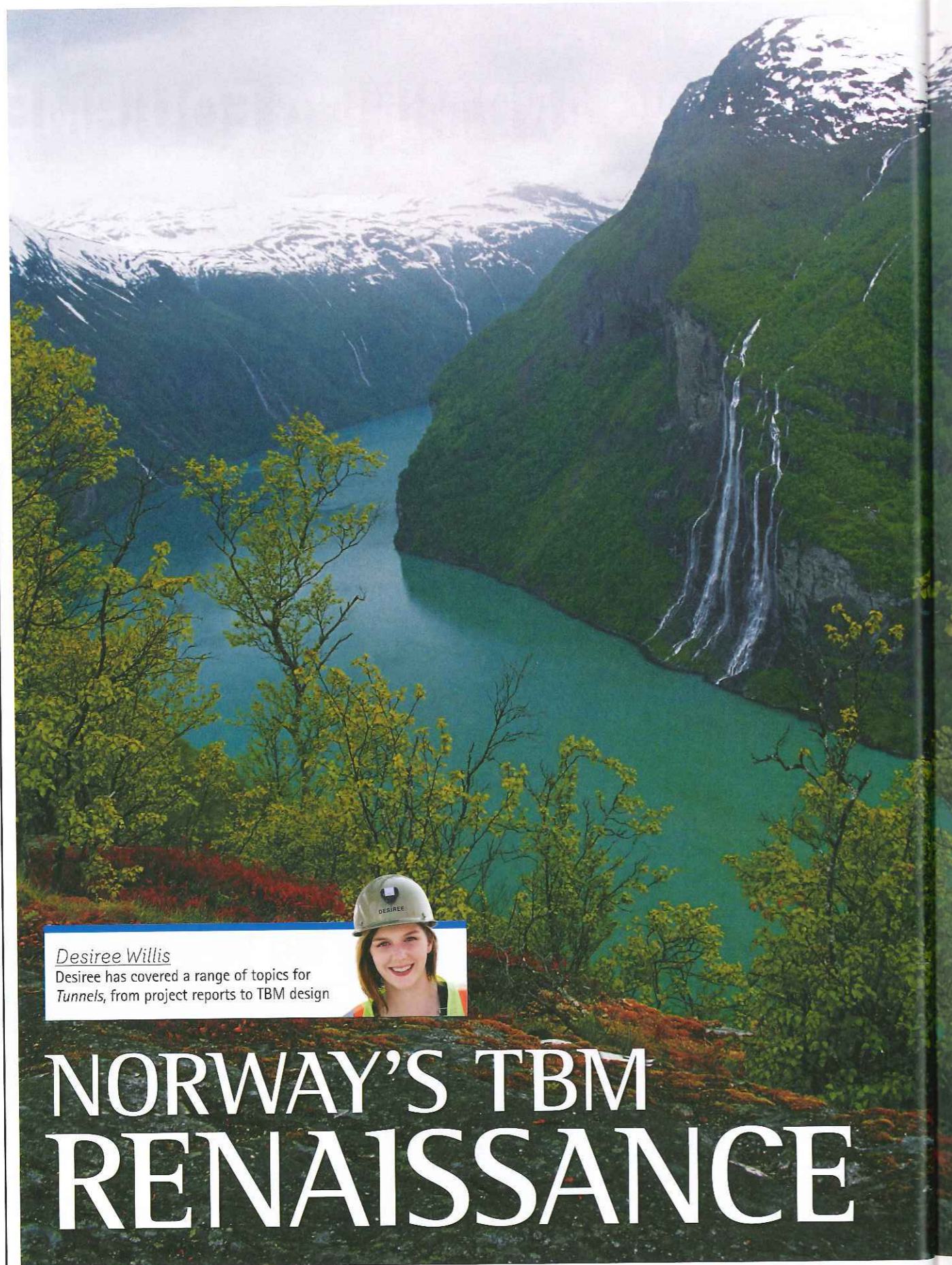


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*Desiree Willis*

Desiree has covered a range of topics for *Tunnels*, from project reports to TBM design

# NORWAY'S TBM RENAISSANCE

**T**HE 7.4KM long headrace tunnel is being built for the Røssåga Hydroelectric Project, and marks the first use of a TBM in Norway in 22 years. Increased demand for hydropower, and longer tunnel lengths, in a country that has specialised in drill and blast, is ushering in new interest in mechanised excavation. Given that Norway builds between 80 and 100km of tunnels per year, the market is primed for a TBM renaissance

## TUNNEL BORING PAST AND PRESENT

"Norway has a long history of tunnelling—in fact there are 1.2m of tunnel for every Norwegian in the country," said Frode Nilsen, managing director of Røssåga contractor Leonhard Nilsen & Sønner (LNS). That long history includes a focus on drill and blast tunnels throughout the country's famously hard and abrasive rock. "We have specialised in drill and blast in Norway, and we are able to do it very efficiently, with very few people at the face, for a low cost. It is a myth though, that this is all done in competent rock. Many foreign contractors think that if you have hard rock, then the conditions must be good, but often we encounter fault zones and other poor quality rock."

In the 1980s and 1990s, a surge in hydroelectric power plant construction drove demand for TBMs to tunnel long head and tailrace tunnels through rocky conditions – approximately 260km of tunnel were driven by TBMs over several decades. At the Svartisen hydroelectric project, a total of six Robbins Main Beam TBMs were deployed to excavate 57km of tunnel through incredibly hard rock ranging from 100 to over 300MPa UCS. To complete the excavation, Robbins developed what were the largest disc cutters in the industry at the time – 19 inches (483mm) in diameter, and installed high-powered motors in each machine to allow between 7,000 and 9,000kN of thrust. The innovative machines achieved then-world records between 1989 and 1991, including a best week of 360.5m and most material excavated in 24 hours, at 1,309cu.m. Since that time, TBMs have been absent from Norway.

The lack of TBMs may have been a combination of factors, including an absence of governmental support for many hydroelectric projects, and more demand for road tunnels. "Drill and blast has always been the dominating method in Norway. This is due to the fact that in Norway we are always excavating a large number of different types of caverns for various purposes and in lots of different sizes. And for this purpose conventional drill and blast fits much better. TBMs are likely not a relevant option to make these caverns. Further, the typical horseshoe-shaped drill and blast cross section is likely more adapted to the needs of road tunnels specifically," said Eivind Grøv, Adjunct Professor at NTNU and Chief Scientist at SINTEF, Norway's largest independent research organization.

The resurgence of Norwegian TBMs at present is a combination of new types of tunnels being proposed and governmental initiatives. "After more or less 20 years standstill in hydropower construction in Norway there is suddenly a boom in this market. This is mainly due to "Green Certificates" issued by the government, which guarantee a set price for all new power plants in production before 2020. In addition, some of the older hydropower plants are in dire need of refurbishment. Building a new tunnel is much more cost effective than taking the plant offline for one to two years for remodelling," said Sindre Log, civil engineer and general manager of Robbins Norway.

Longer tunnels are also driving change: Planned tunnels such as the Follo Line consisting of 20km parallel tunnels are bringing in outside contractors. These international firms are proposing TBMs as the most cost effective method, bringing

High atop the mountains in northern Norway, a tunneling project harkens back to the days of mechanised tunneling in Scandinavia. The crew onsite battles winter temperatures plummeting to  $-32^{\circ}\text{C}$  and works to maintain spares and other supplies at the remote jobsite less than 100km from the Arctic Circle. Robbins technical writer **Desiree Willis** reports

it to the forefront of new tunnel construction in Norway.

## POTENTIAL FOR PRODUCTION

In competent hard rock conditions, TBMs are capable of high rates of excavation – a fact that appeals to Norwegian contractors looking at long distance tunnels. In fact, hard rock machines such as those used at Iceland's Kárahnjúkar Hydroelectric Project have similarly dealt with incredibly cold temperatures and hard, abrasive rock with resounding success. At that project, three Robbins Main Beam TBMs were launched in temperatures as low as  $-25^{\circ}\text{C}$ , excavating volcanic rock of 300MPa UCS or more with extensive water inflows. Despite the challenges, the machines achieved world records, including 115.7m of rock excavated in 24 hours.

While success stories abound, there are still some barriers towards a broader acceptance of TBMs in the Norwegian market. The perception of risk involved in bringing in new technology is one that needs to be addressed. Recent applicable experience by Norwegian firms may also be an issue: "Building up of competence by all parties involved in a sub-surface project is key, including the consultants, the owners and the contractors. This also needs to happen within academia, which is

*Below: The TBM at Røssåga is the refurbished record-breaker from Iceland's Kárahnjúkar Hydroelectric Project, where it chewed through 115.7 m of hard rock in 24 hours*





*Above: Norway's first TBM in 22 years, a Robbins Main Beam, was launched on 16 January 2014*

often on the front line with research and development projects," said Grøv.

#### RØSSÅGA'S TBM CHOICE

When engineers looked at the design of the Røssåga tunnel, a 7.4km long headrace tunnel plus a 450m long access tunnel through hard rock, they began considering alternative excavation methods. Designed to provide an overhaul and addition to existing power stations, the Røssåga Hydroelectric Project involves building a new powerhouse, headrace and tailrace tunnel to increase annual generating capacity by 70MW. The project was originally tendered as drill and blast. However, once contractor LNS submitted an alternative TBM solution, the project owner identified the benefits of the TBM method, and asked for alternative TBM solutions from all bidders, eventually leading to the contract being awarded to LNS.

The 7.2m diameter Robbins TBM chosen by LNS was in fact the refurbished record-breaking machine used at Iceland's Kárahnjúkar tunnels. "I am most proud that LNS has been able to bring TBMs back to Norway after 22 years since the last TBM project. And the reason we managed to do that was because of a very close and good cooperation with Robbins," said Nilsen.

#### MOUNTAINOUS ASSEMBLY

Getting the machine assembled and launched in the mountainous terrain of northern Norway, however, required some serious logistics. The contractor opted for Onsite First Time Assembly (OFTA), making it the first time the assembly method had been used in Europe.

First developed in 2006 at the Niagara Tunnel Project, Robbins' OFTA method allows for components of the machine to be shipped directly to the jobsite, so that the entire machine is assembled for the first time on location.

This method results in reduced shipping and manpower requirements, with proven time savings of up to five months and cost savings up to USD 4M for large diameter hard rock machines.

The solution to assemble the Røssåga TBM using OFTA was strategically planned to expedite the project schedule. "The logistics were complex for bringing the TBM, conveyor system, spare parts, and cutters from all over the world to almost 'the top of the world'," said Nilsen. Good weather resulted in bare road conditions and allowed delivery before winter snow arrived. Altogether, more than 90 loads were delivered to the remote jobsite without any major setbacks.

This included the heaviest component, the centre cutterhead, weighing in at 62,000kg. Five months after the first part was delivered in September 2013, the Main Beam machine started boring. The machine, dubbed 'Iron-Erna' after the country's Prime Minister Erna Solberg, was launched on January 16, 2014.

**We think this may be some of the toughest material ever seen in a hard rock TBM tunnel**

#### HARD ROCK CHALLENGE

As of April 2014, the machine has excavated several hundred meters of tunnel. "The main problem is the rock condition, which is currently 275MPa quartzite. Boring is very slow. We may come into limestone 100 to 200m from now, but for the time being we are in close cooperation with Robbins to find the best cutter for these very difficult conditions," said Nilsen.

Laboratory testing of the unexpectedly hard and abrasive rock is underway, and will help to identify the best cutting tools for the job. Certain sections may be even harder than 275MPa. "We think this may be some of the toughest material ever seen in a hard rock TBM tunnel. We are also analysing the quartz content."

In addition to heavy duty cutters, the machine is outfitted with a Measurement While Drilling (MWD) system to analyse ground ahead of the face. Probe drilling is measured manually or automatically. The MWD system is then used to analyse the rock in detail (hardness, water content, rock mass properties, etc) and can be used to generate 3D-models of the rock mass



*Above: Crews worked quickly during launch to avoid the harsh Norwegian winter, where temperatures can plummet to as low as -32°C*

in order to decide on the rock support. Probe drilling also has the capability of being a continuous operation with a new innovation being tested on the TBM. Drills at angles of five to eight degrees allow for probing and grouting of the periphery on all types of TBMs, and for drilling through the face even when the TBM is not boring. The benefit of the system is to reduce the overall construction time. How much time can be saved depends on the extent of probing and grouting and the capacity of the drilling and grouting equipment, but estimates have savings as high as 20 to 30 per cent. The TBM is currently on schedule for a breakthrough in summer of 2016. The newly renovated powerhouse is slated to go online in spring 2017.

With more road, rail, and hydroelectric projects planned, the Norwegian market is expected to boom in the next five to ten years. "The Norwegian tunnelling industry went sky-high in 2013 with a record-breaking production of more than 6 million solid cubic meters of rock. As far as can be seen from the political scene, there is a drive towards increased infrastructure development in Norway, for road and railway construction and hydropower development," said Grøv.

Grøv's work at the Norwegian University of Science and Technology (NTNU) in Trondheim may play a part in the uptick

#### The Plan View

- Norway's Røssåga Hydroelectric Project is utilising the first TBM to bore in the country in 22 years
- Norway builds between 80 and 100 km of tunneling per year, nearly all of it by Drill and Blast
- There are 1.2 m of tunnel for every Norwegian citizen
- In 2013, Norwegians excavated six million cubic meters of rock
- Governmental initiatives for hydropower projects and longer road and rail tunnels are driving increased interest in TBMs
- With its incredibly hard rock, Norway is seeking research projects that can optimize TBM tunnelin
- FAST-Tunn, a collaborative research project in Norway, has successfully found tool steel mixtures that work more effectively in hard and abrasive rock conditions, which can be applied to disc cutters on hard rock TBMs

of TBMs used in hard rock. Engineers there are hoping to extend cutter life through hardened steel mixtures—a research collaboration by academics, steel manufacturers, the Norwegian government, BASF and Robbins. The project, known as FAST-Tunn (Future Advanced Steel Technology for Tunneling), aims to investigate tool steel mixtures in the hopes of finding a stronger material that can withstand the tough conditions seen on recent hard rock projects. "In hard rock, thrust is very important. The higher the forward thrust, the higher the advance rate; this is not a linear but an exponential function. To be able to push harder, better bearings and better cutter rings are needed. One can make steel that can withstand very high thrust, but then it becomes brittle and abrades faster. A good resistance against high abrasion and increased thrust is the optimal design," said Amund Bruland, Professor in the Department of Civil and Transport Engineering at NTNU, and FAST-Tunn researcher. The research collaboration has been largely successful, and is currently in its last year. "We are sure that we are on the right track as far as achieving steel qualities that can provide the improvements that we are aiming for through this project," said Grøv. With academic buy-in and improvements in TBM tunnelling through extremely hard rock, mechanised boring has a bright future in Norway. For Grøv, subsea TBM tunnelling and more universal machine designs that can handle a variety of conditions are exciting prospects, as long as the technology can be adapted for the Norwegian market. But for Nilsen, the adoption of TBMs is clear-cut: "In Norway, we have deep wallets, high mountains, and deep fjords. We need a lot of tunnels" ☺

# FILLING IN THE CORRALINE HOLES

Drilling innovations, sea platform working and complex logistics were needed for grout injection to improve porous ground for Miami's new port tunnel, **Adrian Greeman** reports

THE NOW finished TBM drives for a new tunnel to access Miami's cruise liner and container port have been one of the world's more complex tunnel jobs in recent times, geologically speaking. Complex ground works, including freezing, mixed-in-place wall panel construction and above all, extensive grouting have all been needed to get a big, 12.95m-diameter Herrenknecht EPBM through the ground.

Two drives of 4,200ft (1,280m) have been required for the new road link (see box), the second finishing in May last year. Fitting out has been under way since, and the completed project opens later this summer.

## WITHOUT EQUAL

An extraordinary limestone rock formation layer in the area causes the main complexity in the job. Like many limestones in the world, this is karstic with the kind of water-eroded fissures and voids that have created significant problems for tunnels like the SMART tunnel project in Malaysia's Kuala Lumpur. But the Florida rock is even more difficult because it is more porous than usual, to such an extent that large diameter tunnelling has previously been considered impossible in much of the state of Florida.

The challenging nature of the rock is caused by its origin in undersea coral reefs. The ancient skeletal remains, compacted as rock, leave it with the texture and structure of a solid sponge, says Laurent Lefebvre a senior vice-president of Nicholson Construction, one of the US' biggest grouting and groundworks contractors. Nicholson is a subsidiary of the major European

*Adrian Greeman*

Is a former editor of and long-standing regular contributor to *Tunnels*



groundworks specialist firm Soletanche Bachy.

The company carried out an approximately USD 40M subcontract to grout the rock on the Miami port tunnel alignment for main contractor Bouygues Civil Works Florida, which is doing the overall USD 640M construction work. Bouygues itself is also a subsidiary of a European firm, the French Bouygues Travaux Publiques.

One of eight different ground layers, the corraline limestone is found about 42m deep, which coincides with much of the alignment of the twin bores. Getting through it would be problematic, Bouygues decided, for several reasons. Firstly it is low in fines making standard EPB operation difficult because a pressure resisting plug would not form easily in the screw conveyor. Secondly the open structure makes the water filled rock potentially unstable.

"That became more apparent after an intensive programme of ground investigation carried out by the contractor," says Lefebvre. According to information from Bouygues' geotechnical director Roger Story, this lasted for nearly two years. Drill samples were taken every 10m and there were additional tests done using ultrasound, cone penetrations, permeability testing and camera log surveys. Samples were sent to Bouygues' European headquarters for analysis.

The contractor went further, sinking five shafts at the tunnel low points, each 2.5m in diameter.

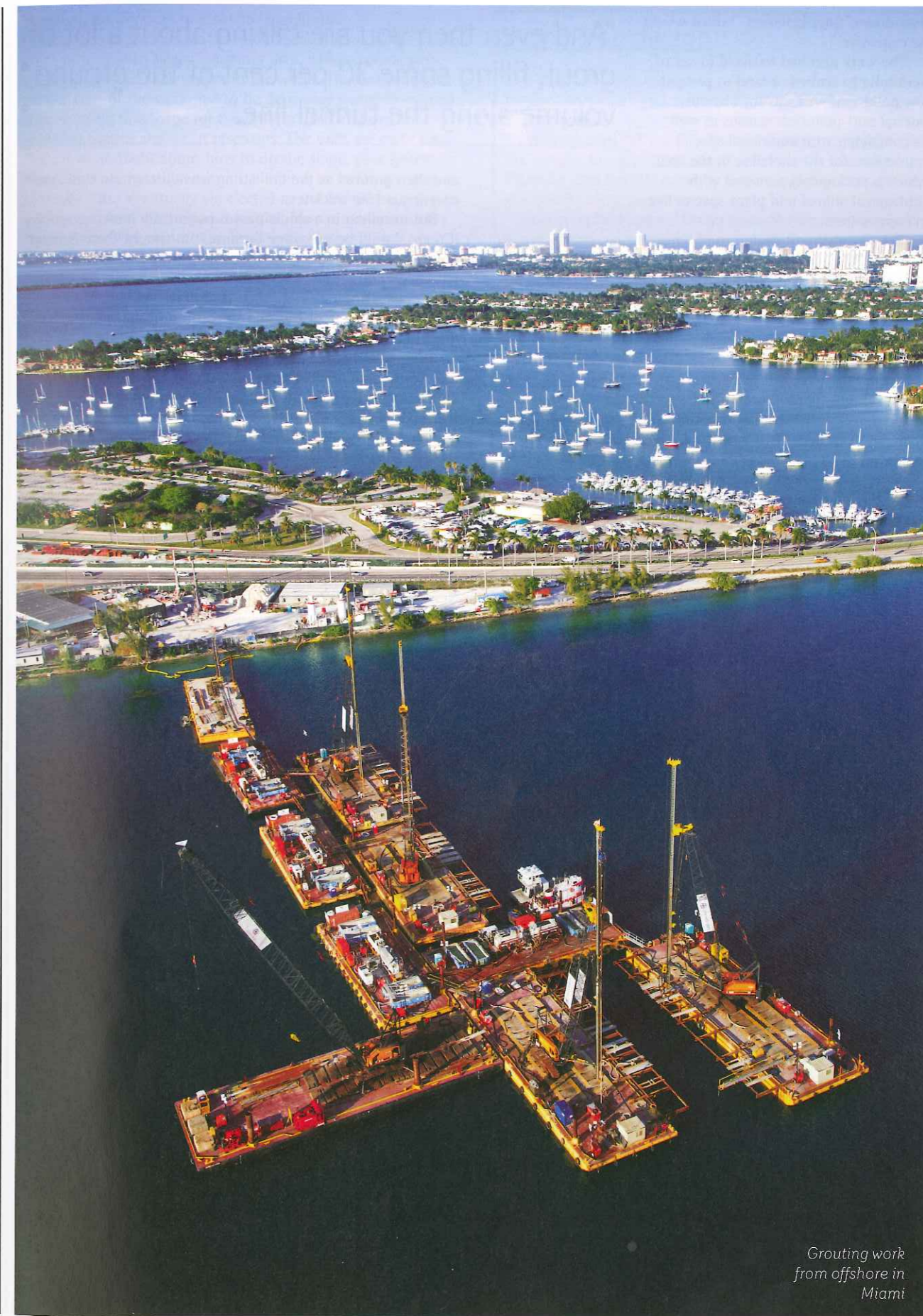
With increased understanding of the ground, Bouygues' solution, discussed with manufacturer Herrenknecht, was a modification to the 12.8m-diameter EPBM. It would be provided with a pressurised water circuit from the end of the screw conveyor, allowing the machine to operate somewhat like a slurry machine, with water pressure supporting the face and water transport for the spoil.

But the contractor also decided the corraline ground layer would need extensive grout treatment along much of the alignment and part of its preparation was to devise and test a system to do that. Lefebvre says Nicholson was one of several grouting companies called in for discussions and estimates by the contractor as it devised a grout that was sufficiently viscous or thixotropic to fill the "sponge structure of the rock" but without flowing too far from the grouting points.

The challenge was to fill the rock along the alignment but to avoid grout going too far, for both cost and environmental reasons. "You don't want to fill the voids all the way to Miami

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Grouting work from offshore in Miami

downtown," says Lefebvre, "which would be expensive."

The work also had to avoid losses of bentonite to seabed or land to prevent any pollution. This was for obvious normal anti-pollution reasons as well as complying with additional special restrictions for the shoreline in the area, which is ecologically sensitive with subtropical animal and plant species like mangrove trees.

The viscous grout design used a mix of bentonite, sand and cement as well as additives and this was combined with a tight pattern of drill holes to achieve the just coverage required.

#### PATHFINDING

"And even then you are talking about a lot of grout, filling some 30 per cent of the ground volume along the tunnel line," says Lefebvre. "It is more a filling than a grouting operation."

Along with finding a restricted flow grout, Bouygues also wanted to have the grout installed in stages through the thickness of the ground layer, using a so-called 'downstage' method. Upstage is more usual, where the ground layer is drilled to the bottom of the layer

"And even then you are talking about a lot of grout, filling some 30 per cent of the ground volume along the tunnel line."

and then grouted as the drill string is withdrawn, in this case covering a 15m thickness.

But installing in a single pass is potentially more hazardous if there should be a leakage because, put simply, there is more unset grout to escape. Downstage does the work in smaller passes, drilling a short length, in this case just over 3m, and withdrawing and grouting, then re-drilling through this first layer to do the one below, and so forth until the full depth is done in about four sections.

"Normally that is time consuming because you have to remove the drill head and then grout and then re-install," says Lefebvre. "So we came up with a one-pass method that uses a two-way valve system at the surface – it has been patented – and could drill and grout and then re-drill without withdrawing the drills.

"Without that method we could not have dealt with a very demanding schedule." It helped the company when the time came to propose a bid to Bouygues.

Nicholson won the bid for the work in July 2011 at which stage Lefebvre was joined by project manager Luca Barison from the company's special projects group based in Denver. New challenges now awaited, not least a limited 10-month

*Below: Nicholson used a downstage method for grouting in Miami*



period to do the work in restricted conditions.

The tunnel line crosses the main channel used by the cruise ships passing into Miami's harbour area, which include some of the biggest of such vessels in the world. That meant about 80 per cent of the work had to be done over water, from spud barges, using one barge for the drill rig itself and one for its grouting pumps and grout reservoirs. The drills are quite large. "When we thought about how to do the single pass system 40m down we initially were not sure how to tackle it," says Lefebvre. "But eventually we elected to use a drill guide system with a long lead 40m high suspended from a conventional American crawler crane." The leads were designed by a Nicholson sister company based in Canada.

"But to meet a quite demanding schedule we needed to have more than one drill at work," says Barison. "In fact at the peak point we had four."

That meant some eight barges arranged out into the channel forming a 'bridge' almost between one side and the other. The barges were linked together with walkways and also to shore with a bridge connection.

That sounds simple enough and Barison says that obtaining barges for hire was not difficult; Miami is near enough to the Gulf of Mexico offshore oil area to make such equipment readily available. But the arrangement had to be easily set up and dismantled because work could only be done within limited time windows to fit in with the harbour schedules; for the harbour authority priority goes at all times to the big cruise ships, which leave every few days. For these to pass the channel had to be clear.

Clearing the passage took some hours as did setting up again. Nicholson had two tug boats permanently on hire for this work. Once operations were underway there had to be 24-hour working to make maximum use of time in windows which were sometimes just two or three days.

Even when the barges were in position, logistical issues were important, most of all supplying the grout mix and in the large quantities required. Nicholson explored the Miami area for ready mixed suppliers but none of them could handle the specialist mix needed and certainly not in large volumes.

"We needed our own batching plant," says Barison. Fortunately the worksite for the main contractor was big enough to accommodate a grout plant on the Watson Island side. This was connected to shore via a causeway link along which trucks could pass.

Transporting the mix to the barges was done with trucks; feeding concrete pumps at the shoreline connected to a pipeline through the barge connection bridge. These filled agitator tanks on the supply barges where the mix could be kept relatively fluid while it waited to go down to the limestone layer. Some 60-70m<sup>3</sup> had to be pumped each hour. Each of the drill and grout reservoir pairs had its own pumpline.

"We thought about boats but it would have been too difficult," says Barison. An advantage of the bridge was that it allowed the first 20m of shoreline to remain untouched, an environmental constraint in the contract conditions. For the drilling operations themselves there were technical and environmental constraints. First was to ensure that the grout did not spill or enter the water.

"The drilling was all done inside an outer 300mm diameter casing, which was installed first and keyed into the seabed," says Barison, "so that any grout coming back up the drill hole would rise all the way to the barge."

To contain it there, the barges were all fitted with 150mm 'lips' around the sides that also served to hold in any spillage.

"We also had divers on standby all the time in case there

#### Picking up the tab

Port of Miami access tunnel is a twin bore connection into the commercial harbour area to the north of the famous resort and beach city areas.

When opened this year it will provide a direct route into the complex for up to 1,600 trucks daily from the interstate highways I395 and I95; currently they have to pass through the city causing congestion.

It is being built under a design-build-finance-operate-and-maintain concession by a consortium, The Miami Access Tunnel Concessionaire (MAT). MAT is part of a public private partnership with the City of Miami, Miami-Dade County and the Florida Department of Transportation. Contractor Bouygues, which is carrying out the work, has a share in the group.

Under the concession agreement, FDOT will make milestone payments during the construction period, upon the achievement of contractual milestones. Once construction is completed, the concessionaire will receive payments contingent upon service quality. The tunnel will be returned to FDOT at the end of the contract in October 2044.

The main part of the work is twin drives of just over 1,200m, which were carried out by a single Herrenknecht TBM passing first eastwards, and then returning after a turning operation on the Dodge Island side of the channel. Watson and Dodge Islands are artificial islands created to form the port.

Miami is anticipating significant growth in the expanding cruise trade, and also in container freight, particularly after the project's completion.

## 300

The diameter in millimetres of the casing for the drilling

## 40

The height in metres to suspend the drill guide system from a crawler crane

should be any issues," adds Barison.

The drilling itself was monitored in real time firstly using a Lutz system for the drill parameters such as rotation, pull down forces, water pressures and flows and then a software system, Grout IT, from Soletanche for the grouting work.

"This was connected to the office onshore and allowed us to monitor and record all the crucial parameters for the grouting, to assess how it was completing," he says.

The drilling itself was primarily on a 5m grid along the line of the tunnels, beginning with the eastbound drive from Watson Island across the to the other side. Grouting had to be done a month before the TBM reached any particular position.

"It was a bit tight at the beginning as we spent a while sorting out the methods and did not begin drilling until November," recalls Lefebvre.

"So that was a little tense but once we got going things were more relaxed," says Lefebvre. The grout progress went well and was well in advance of the TBM, eventually even finishing a little ahead of the schedule.

"We also some landside drilling to do," adds Barison, "including drilling at an oblique angle for the shoreline areas which were out of bounds for ecological reasons" ☺

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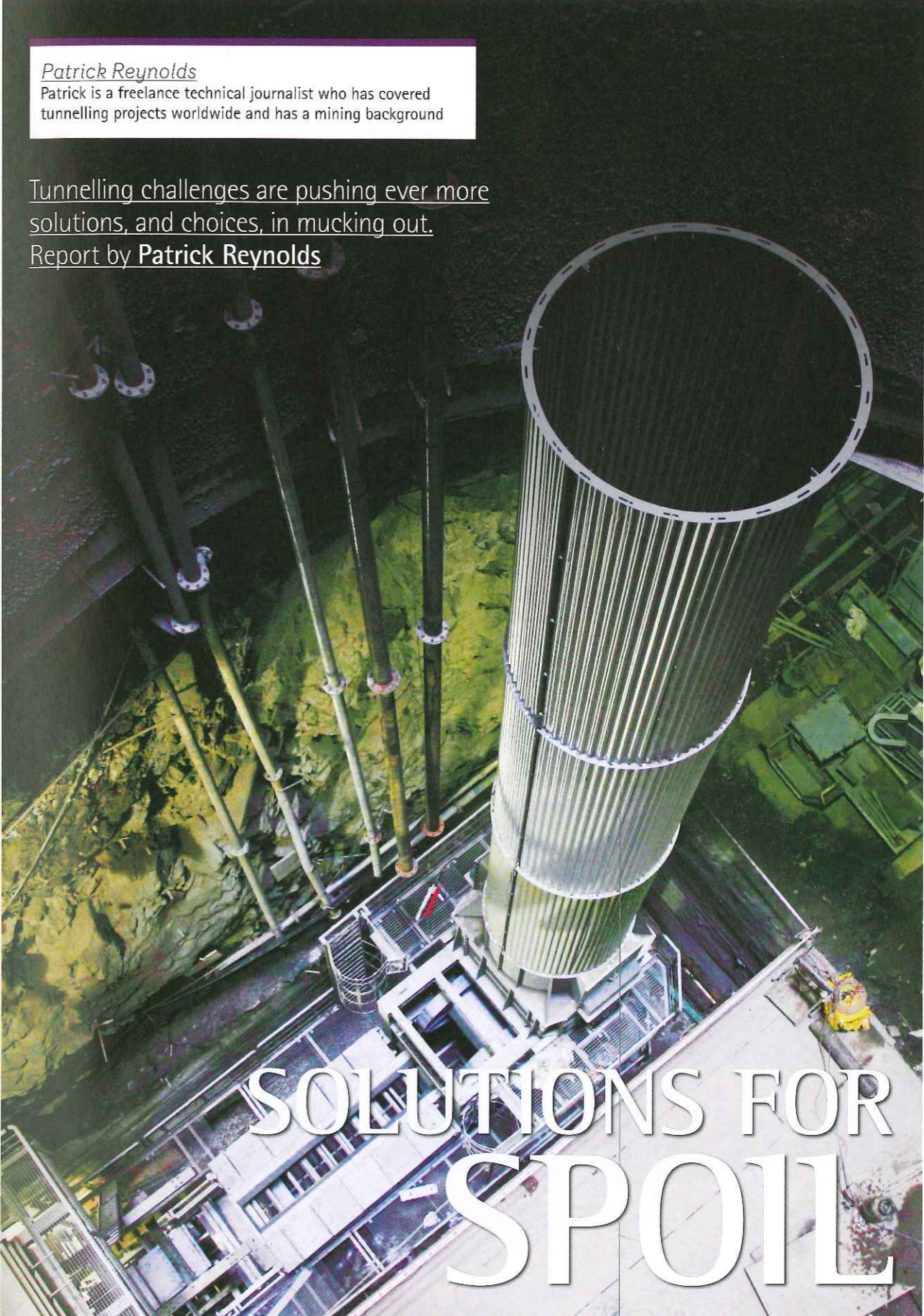
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Tunnelling challenges are pushing ever more solutions, and choices, in mucking out.  
Report by **Patrick Reynolds**



**SOLUTIONS FOR SPOIL**

**W**HETHER THEY be short or long, deeper or steeper, the tunnelling challenges on many projects are often pushing new limits to achieve necessary solutions in mucking out, and adding ever more choices.

As Bruce Matheson, sales and marketing director at Terratec, observes, "Like everything underground, there can be no blanket solution – everything is case by case, and it is dependent on the project, time scale, budget and, of course, the equipment the contractor happens to have."

Tunnels' brief sampling of projects – excluding slurry pumping – has shown varied combinations of wheels, rails and conveyors in play. In addition, there is more new loading kit to choose from (see box, page 54).

As Matheson comments, "The market is a bit confused out there, choices are made that you would not think of first off – but in the end they work out great – it's all about thinking outside the box."

#### BELTS AND EPBM

While it has a growing range of excavation equipment, Terratec's journey in spoil removal is focused on continuous conveyor system, and includes its own design of a floating tail piece, patented almost 22 years ago and used then as part of the tunnelling package for the Prospect Reservoir scheme, in Australia.

For other projects, the firm has provided different solutions from trailing

bunker conveyors to overland conveyor transfer systems. Terratec, he says, prefers to use a solid woven belt as its 'belt of choice', a product connected with their origins deep in the Australian mining industry, and built on that sector's generations of muck transport experience.

Matheson says, "The beauty of it is the increased tension it can take, and on top of that, as it's a matrix weave structure, it is basically rip proof."

Projects recently supplied with Terratec conveyors as part of tunnelling packages of various sizes, include works on two metro schemes: Line 2 in Santo Domingo, which also called for a refurbished 9.56m diameter EPBM; and, most recently, Bangkok metro's Blue Line Extension project which called for a 3.2km long belt system along with a 6.44m dia EPBM – and both having to be capable of a 160m radius curve.

He says that one of the interesting aspects of the Blue Line system is that the belt feeds skips on a car passer in the shaft. The skips are lifted out and dumped or can be stockpiled in what is a very congested site in downtown Bangkok. The contractor is Italian-Thai Development.

"This saved the contractor the expense of a vertical conveyor and allowed them to use existing equipment," he says. "It's all about being flexible and that's something we pride ourselves in."

Another TBM and continuous conveyor package, this time from Robbins, is currently excavating on quite a different project – opening up two decline tunnels at Anglo American's Grosvenor coal mine, in Queensland, Australia. The machine is a hybrid single shield/EPBM, and the tunnelling system is operating on steep grades – 1:6 and 1:8, respectively – through mixed ground conditions, though mostly sedimentary hard rock is anticipated.

Robbins notes that continuous conveyors have been 'tried and tested' with hard rock TBMs for decades, but there is a surge in growth with soft ground shields. It comments that efficiency advances coming from electric variable frequency drives could give conveyors 'potential to corner the market' for mucking out behind EPBMs.

The ability of belt wipers and scrapers to 'deal with wet,

*Opposite, below:  
Loader and rail  
wagon on the  
East Side Access  
project in New  
York City*

*Below: Robbins  
TBM at a coal  
mine in Australia*



## VFDs could give conveyors potential to corner the market for mucking out behind EPBMs

sticky material as well as hard rock,' means, says Robbins, that while projects have variable geology, 'ground conditions have little bearing on conveyor operation.'

#### STEEP AND LONG

Another project where the drives are steep and the tunnels long, and is using a conveyor solution for mucking out, is the tunnelling on the east end of the Ryfast project, near Stavanger, in Norway. However, here the rock is hard and, unusually in working with long conveyors, the excavation method is drill and blast.

Contractor Marti is blasting the twin tunnels through gneiss and opted for the spoil removal solution as it is building part of what will be the world's longest subsea road tunnel scheme. Over less than 8km, and after a relatively shallow start from the Solbakk portal, the contractor's section of the Ryfylke tunnel – the longer of the two in the Ryfast scheme – will reach 230m below sea level at its lowest point, having descended mostly at a grade of seven per cent.

Sandvik, which has supplied the jumbos to the Solbakk works, observes that Marti has been able to draw upon its TBM experience to conceive of adopting an extensible conveyor system for mucking out.

The spoil is taken a few hundred metres back from the face by wheel loaders, which tip the rock into a feeder-breaker system before the crushed rock is passed on to the conveyor, and discharged beyond the portal.

The manufacturer adds that the conveyor solution should help improve safety as it will help to minimise vehicle movements in the tunnels. It observes, too, that "running fully loaded dump trucks for long distances up such a slope would be extremely demanding on the equipment."

With long tunnels presenting major challenges for mucking

## 230m

The depth below sea level to be reached by the Ryfylke tunnel on the Ryfast parent project in Norway

out, another instance of such a project is the Alimineti Madhava Reddy (AMR) water tunnel, in India. At 43.5km long when finished, it will be the world's longest tunnel built without intermediate access.

One of the two Robbins TBMs on the project met problems when fractured rock damaged both the shield and conveyor belt, requiring both repairs to be made and deflector plates added at the cutterhead chute. But, even apart from those difficulties, the task of operating and maintaining such a long continuous conveyor system is "a challenge in itself," says Jim Clark, the manufacturer's country manager.

#### DEEP

Another long tunnel is the Emisor Oriente wastewater scheme, in Mexico City, which is being bored by six TBMs – split evenly between Herrenknecht and Robbins. While length is one of the hurdles for mucking out, the other excavation challenge does not arise from steep grades because it is a hydraulic tunnel but, instead, comes from its general depth – the shafts range in depth from 50 to 150m.

The 62km long tunnel system has had to located deep underground as a key part of the major drainage solution to the capital and its suburbs. The challenge for tunnellers, then, is mucking out from the deep shafts on the project, and a sites in varied situations.

Supplier H+E Logistik describes



its 5.3km long conveyor with 500m horizontal belt storage capacity supporting one of the three Herrenknecht EPBMs on the project; the manufacturer provided two 8.7m shields and a 8.9m machine. H+E is part of the same group.

On the project, Robbins has used J-type vertical conveyors and vertical belt cassettes supporting its trio of 8.9m diameter EPBMs. One vertical cassette is 34m high, allowing for extension and splicing of the belt on a small footprint at tight shaft site.

Heights of vertical conveyor systems have been growing to meet, and overcome, similar large lift challenges in the recent spate of deep tunnels. On the Mumbai Water Tunnel IV project, the vertical conveyor raised muck 122m up the shaft. Behind the 6.25m dia Herrenknecht shield, the entire H+E conveyor was 6.8km long with 500m horizontal belt storage capacity.

"For vertical conveyors of that life height it is always a challenge for installation of the pocket belt itself," says Martin Koch, senior project manager with H+E. He adds, "As the belts have a high weight per meter, and has to be lowered into the shaft from the top. Depending on the site and available space, it is done by special machinery to lower the belt step by step."

#### SHIFTING CHALLENGE

Sometimes, though, more complicated circumstances arise in and around water tunnels, such as the varied vertical alignment at Ontario Power Generation's Niagara Power Tunnel, and the surface waterways that needed to be crossed by the mucking out system – again, a conveyor and TBM



#### Loading answers

Sandvik and Atlas Copco have new offerings in loading for the tunnelling market.

##### Sandvik

Sandvik introduced the LH204 loader to the mining sector in April, and the product would be equally applicable for tunnel projects, says Tomi Pikala, marketing manager for loaders.

"It's designed for underground mines but nothing prevents you to use it in tunnelling or even open pit," says Pikala. He adds, "It is possible and a very handy tool also for tunnelling projects, but some bigger models like LH307 and LH410 are more common due to physical size and capacity."

While the LH204 can work well in a 3m by 3m tunnel section, it is capable of operating within a tighter space, such as 2.5m by 2.5m, says Pikala. It was designed for supporting the mining of narrow-vein ore bodies, and has a 4 tonne capacity.

"Minimum tunnel size depends on local regulations," he notes.

The new feature in the size class is locating the operator in the rear frame away from spilling rocks. "This improves safety quite a lot," says Pikala. The loader also has an onboard diagnostics tool, uncommon to the size class, he adds.

In discussing operating in tight spaces, he also points to 'some interesting existing technologies' – side-tipping buckets, and ejector buckets with push plates to speed up the discharge process.

##### Atlas Copco

While Atlas Copco has further filled out its loader range with the introduction of the 18 tonne capacity Scooptram ST18 loader, for long and tighter mines and tunnels the company has on offer the Haggloader for continuous loading.

Atlas Copco launched the Scooptram ST18 at the end of last year. In the announcement, product manager Ben Thompson said the 'long-awaited' loader had an optimised bucket, meaning "better muck pile penetration, faster acceleration and faster dumping."

He added: "The result is a better load factor on the truck and, in the end, a higher tonnage per month."

The Haggloader is available in different sizes as well as mountings – on wheels (7HR & 10HR models), rails (8HR) or crawler tracks (9HR). Fully capable of loading itself, the Haggloader can be equipped either with digging arms or a back-hoe system to load the conveyor. Tunnel drift areas for the models are minimum 8m<sup>2</sup>, except for 10HR which is minimum 14m<sup>2</sup>.

Atlas Copco says the new system is a system-match with several of its haulage vehicles, such as the 10HR model working with the Minetruck MT42. In addition, the Haggloaders can work with its HaggCon shuttlecars, adds the manufacturer. The wagons have four capacities from 6m<sup>3</sup> to 14m<sup>3</sup>.

solution.

A large diameter bore, the tunnel was commissioned last year and now conveys extra water to boost generation at OPG's Sir Adam Beck power plant. It is a little over 10km long but the original design featured grades of more than seven per cent at each end.

During excavation, the overall result was a net lift of 40m, but the slopes and also horizontal radii led to changes in tension along the length of the conveyor. H+E supplied the conveyor.

During construction, geological problems for the TBM bore led to a redesign of the tunnel's vertical alignment, and introduced yet more grades.

In part, the re-design of the mucking system involved relocating the booster drive.

Once the spoil from the 14.4m diameter Robbins machine was up on the surface, the challenge at Niagara was not over. The conveyor transfer system had to get over the wide waterways, and a large single-span bridge had to be installed using cranes.

Contractor Strabag pulled back months from the revised



programme deadline, and at less cost, which enabled the client to start generating extra electricity and earning more revenue sooner than had been anticipated when the tunnel was suffering overbreak during excavation.

#### NOT UP, BUT AWAY

While the Niagara setting offered tunnellers uncongested, open space to arrange the surface portion of their conveyor system, no such luxury is afforded in urban environment, especially in the likes of New York.

On the East Side Access (ESA) project, being developed by the city's Metropolitan Transportation Authority (MTA), the challenge was how to muck out from caverns being blasted out not below the expensive real estate of Manhattan. The challenge was a bit trickier still: the caverns are below the existing, low-level "Train Shed" where commuters already embark and disembark before going upstairs – to the concourse of the world-famous landmark, and cathedral-like space, of Grand Central Station.

No way to get up and out, of course. However, as with many long tunnels, the answer to removing spoil from the massive cavern excavations was to take it out the way the plant got in. In the case of ESA, a series of hard rock TBM drives had bored their way below parts of Manhattan, and the tunnels would form the main link in the future commuter extension of the Long Island Rail Road (LIRR).

As the caverns would house the future LIRR terminal below Grand Central, the TBMs came all the way into, and beyond, the station zone, carving out much of the voids in repeated jabs. And then they were gone, retracted, and dismantled.

When the underground works contractor Dragados/Judlau JV then moved to blast out from the stacked bores, taking



out headings, pillars and benches, they elected to cavern spaces to muck out when a combination of wheeled loaders and rail wagons.

The spoil trains would then shuttle out along the bored tunnels, snaking off towards Queens to emerge at the surface.

The excavation and mucking task completed, construction has moved on to cavern waterproofing and lining, and ESA is looking at an in-service target date of 2020

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[This paper begins in the previous issue, *Tunnels* May 2014, p.53. Due to a printing error, the final portion is reprinted here]

SUGGESTIONS FOR TUNNELLING PRACTICE

In this paper, options and limits of processing and analyzing of machine data were demonstrated. Parameters acting on cutting wheel and shield movement were observed.

It was shown that the relevance of automatically generated raw data without further processing is very limited for interpretations of soil conditions or even be particularly misleading. Various influences on TBM raw data are shown in figure 14 (*Tunnels* May 2014, p.65).

Raw data may be split into different components. Excavation-specific data components (influences of soil conditions and cutting wheel state) in many cases show only little portions on raw data, whereas excavation-independent data components like face support force or friction force show major influences.

Thus, it is recommended to separate excavation-specific data components as accurately as possible. Although theoretical approaches are given, subsequent evaluation of significant

■ This work was supported by the German Research Foundation (DFG) within the Collaborative Research Center SFB 837 (Interaction modeling in mechanised tunnelling) and by Herrenknecht.

values is difficult because of very alternating conditions in the course of shield driven projects.

Measuring errors may occur as a result of strong vibrations, temperature and moisture deviations in addition to large cable length, influencing complicated measurement setups. Frictional forces may change in course of construction as a result of wear effects and entry of fines (mud, dust, clogging).

Thus, the significance of processed data is influenced negatively and subsequent estimations, or even corrections can barely be realised. Despite this persistent inaccuracy, processing of raw TBM data is very useful, because soil conditions will show larger influence on excavation-specific data components as on the raw data.

Variations of machine data may be promptly detected as a result of technical or excavation-specific reasons on the one hand. On the other hand, little variations of excavation-specific data components will not lead to any variation of raw data.

Continuous observation of the excavation-specific data components may form the chance to recognise critical influences (e.g. clogging) much earlier. For future TBM projects, suggestions are offered in Table 2 (see *Tunnels* May 2014, p.65).

It is strongly recommended to use excavation-specific data components for all kinds of analysis focusing on the interaction of machine data and ground conditions.

After identification of technical and human influences it has to be regarded that excavation-specific data components are influenced by ground conditions and state of cutting wheel as well.

Cutting wheel design has to be taken into account when comparing different projects. Influences of tool wear and clogging have to be regarded on every project.

For an exact determination of those influences, continuous documentation at the project site is mandatory

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[www.demosfuur.com.tr](http://www.demosfuur.com.tr)

Fire Protection and Safety in Tunnels 2014

10-11 September 2014  
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Fire Protection and Safety in Tunnels returns after last year's event in Copenhagen, which set new standards for case study, industry driven presentations and networking opportunities. Norway is hosting the sixth annual FPST event, a country with an impressive network of more than 900 road tunnels alone.  
[www.arena-international.com/fpst](http://www.arena-international.com/fpst)

15th Australasian Tunnelling Conference

17-19 September 2014  
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[www.atstunnellingconference2014.com](http://www.atstunnellingconference2014.com)

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InnoTrans

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An international platform for buyers and sellers of passenger and freight transport technology, InnoTrans focuses on railway technology. The Tunnel Construction segment will be accompanied by the International Tunnel Forum, which will feature a series of international discussions  
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[www.expotunnel.it](http://www.expotunnel.it)

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29-30 January 2015  
Tyrol, Austria  
Wolfgang Kusterle and his team welcome you to the Conference and Exhibition Shotcrete 2015 at the Alpbach Conference Centre. Knowledge and experience do not help, if they remain hidden. This platform has gathered shotcrete specialists for 25 years, in a surrounding field where the exchange easily takes place.  
[www.spritzbeton-tagung.com](http://www.spritzbeton-tagung.com)

ISRM Congress 2015

10-13 May 2015  
Montreal, Canada  
Held in conjunction with the CIM Convention for 2015, the International Symposium on Rock Mechanics holds its international conference every four years. A one day symposium on "Shale and Rock Mechanics" is planned.  
[www.ISRM2015.com](http://www.ISRM2015.com)

World Tunnel Congress 2015

22-28 May 2015  
Dubrovnik, Croatia  
WTC 2015 heads to the Dalmatian Coast as the event returns to Europe. Further details to be confirmed.  
[www.wtc15.com](http://www.wtc15.com)

RETC

7-10 June 2015  
New Orleans, Louisiana  
The Underground Construction Association's biennial conference.  
[www.smenet.org](http://www.smenet.org)

## British Tunnelling Society

The BTS has a membership of almost 700 individual and 60 corporate members. It is one of the most vibrant gatherings of professional tunnellers in the world and traces its history back to its founding in 1971. Events are hosted at the Institution of Civil Engineers in London from 5.30pm every third Thursday of the month.

Harding Lecture

19 June 2014  
The Harding Lecture is named after the founder Chairman of the Society, Sir Harold Harding and is given every second year. The lecture is given this year by Donald Lamont, with the title: 'Health and Safety in Tunnelling - Evolution and Revolution'

Crossrail Western Tunnels, urban tunnelling through the capital

18 September 2014  
Further details to be announced.

"What could possibly go wrong with a site investigation in chalk?"

16 October 2014  
A review of case histories and the importance of site investigations and particularly the analysis of the results. To include case histories of good and bad practice. Speaker: Rory Mortimer, Brighton University

Bond Street Station Upgrade

20 November 2014  
Further details to be announced.

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