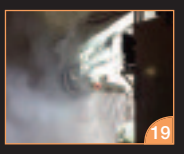
JANUARY 2011

tunnels & tunnelling INTERNATIONAL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45

Special report: Australasia

T&TI checks out how the Australasian market is coping with the global recession

Technical: Worker safety

Various aspects of keeping tunnel workers safe and healthy, including new CEN machinery standards

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World's largest EPB TBM

A 15.62m-diameter Herrenknecht monster for Italy

ZURICH: BREAKTHROUGH AT THE DIAMETER LINE.

After only two years of tunnelling, the task was completed on November 22, 2010. The tunnel workers reached the target shaft of the Weinberg Tunnel with the convertible S-451 Herrenknecht Mixshield (∅ 11.24m).

The tunnel will connect the Oerlikon station with the new Löwenstrasse underground station directly beneath the main station Hauptbahnhof. It forms the core part of the Diameter Line, a dual track railway connection right beneath city. The capacity of the Zurich main station will increase by 100,000 passengers per day after the opening which is scheduled for 2010.

The experienced tunnellers mastered the tunnelling procedure with the high-tech machine beneath the city center safely and successfully. Both the tunnelling in hard rock and in the final, particularly demanding around 150 meters beneath the Limmat River in unconsolidated rock and groundwater were mastered with bravura.

Herrenknecht is proud to have been involved again in an outstanding and challenging Swiss tunnel construction project after its participation in other projects, such as, for example, the Islisberg Tunnel, the Zimmerberg Base Tunnel and the Gotthard Base Tunnel.

ZURICH | SWITZERLAND

PROJECT DATA	CONTRACTOR
S-451 **Mixshield (convertible)** Diameter: 11,240mm Cutterhead power: 3,200kW Tunnel length: 4,416m Geology: molasse, unconsolidated rock	ATW Arge Tunnel Weinberg: Implenia Bau AG, Wayss & Freytag AG, Bilfinger Berger AG, PraderLosinger SA

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

www.herrenknecht.com

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comment

Making the case for tunnels

The UK National Grid, which is responsible for maintaining the electricity transmission network, late last year called for input on the arguments for and against undergrounding the electricity lines for new power generation.

It is critical that the industry responds and puts forward the best case for tunnelling. It is also critical that the industry understands the current drivers in the energy debate so that it puts forward the most politically astute arguments.

The UK power sector is responding to the 2006 government energy review that gave the green light to a new generation of nuclear power stations. The issues behind the UK energy review are mirrored in almost every developed country globally. If the industry can set a precedent for undergrounding electricity lines in the UK it could help set a standard for the rest of the world.

In developing the plan for renewing the UK's aging energy infrastructure, the review was driven by two main factors: energy security and protecting the environment. These two factors need to be present in the arguments for undergrounding the electricity lines.

The first point, security, is the easiest to fulfil. Tunnels offer complete protection against the weather as only the portals are subject to the outside world. This means the electricity lines will be protected against long-term weather corrosion as well as storms. This same restricted access can also protect the lines against attack. Maintenance of the lines is also simpler as running the lines through tunnels removes the issues of working at height.

The second point, environmental impact, will be a much more heated debate. There are obvious environmental benefits to tunnelling. The most important in the case of the electricity network is aesthetic: removing the unsightly electricity pylons from crisscrossing the countryside. However, there are also arguments against, such as the amount of energy required to construct a tunnel and the environmental impact during construction.

Each of these arguments will be looked at alongside the cost of tunnelling. In congested cities and urban areas, going underground may be the only solution. Hong Kong has in recent years completed the construction of four major power cable tunnels each some 5km long. Singapore has some 30km of power cable tunnels in design. But it will be more difficult to justify cable tunnels spanning the length and breadth of the country.

The National Grid consultation is open until mid March and will form the company's new approach to undergrounding cables. Now is the time to make the case for tunnelling.

Jon Young

contents

On the cover

World's largest EPBM, A 15.62m-diameter Herrenknecht monster for Italy (page 10)

In the supplement

T&T Asia visits the stage two launch site for Singapore's Downtown metro line

TUNNEL WITH CONFIDENCE START TO FINISH...

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In 2008, Lovat combined its underground expertise with the resources of Caterpillar, a company that understands large scale manufacturing and the importance of research and development.

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Crossrail running tunnels award

GREAT BRITAIN

Crossrail has announced contracts worth around GBP 1.25bn (USD 1.98bn) for the twin-bore running tunnels of the Crossrail project.

The winning bids are:

Contract C330 - Western running tunnels between Royal Oak and Farringdon – to joint venture of BAM Nuttall, Ferrovial Agroman (UK) and Kier Construction.

Contract C305 – Eastern running tunnels in stretches between Limmo Peninsula and Farringdon, Limmo Peninsula to Victoria Dock, and Stepney Green to Pudding Mill Lane – to JV of Dragados and John Sisk & Son (Holdings).

C410 – Early access shafts and sprayed concrete lining works for Bond Street and Tottenham Court Road station tunnels – to JV of BAM Nuttall, Ferrovial Agroman (UK) and Kier Construction.

C510 – Early access shafts and sprayed concrete lining works for Whitechapel and Liverpool Street station tunnels to JV of Alpine BeMo Tunnelling, Balfour Beatty Civil Engineering, Morgan Sindall (Infrastructure) and Vinci Construction Grands Projets.

Crossrail intends to merge contracts C300 and C410 as a combined award to achieve cost efficiencies within the new delivery programme. The contracts will actually be awarded after 10-day standstill period under European procurement requirements.

Other, unsuccessful shortlisted bidders, as announced in December 2009, are Bilfinger Berger/Costain/Skanska Construction UK, and Bouygues Travaux Publics/Laing O'Rourke Construction/Strabag, although Bouygues is also part of the C300 joint venture.

The 42km of tunnelling being awarded will require seven, 7m od, TBMs, to be manufactured in Europe, to make the 10 drives for 6m-diameter running tunnels. All drives will have pre-cast concrete segmental linings of bolted construction. Referring to the map the first Drive X will employ two EPB TBMs, as will all the other drives except the Thames Tunnel (Drive H) that will use one slurry-shield TBM with two available cutterheads to bore mainly through chalk. The EPB TBMS will be tackling a fixture of London Clay, sand and gravels, operating nearly 24-hour a day, 7-days a week to minimise the risk of settlement.

These contracts cover the construction of 18km of twin-bore tunnels underneath central London with TBMs for primary excavation, leaving around another 3km. Tunnelling will start in late 2011 with the first TBM due for launch in Spring 2012 to bore from Royal Oak towards Farringdon Station (near the new home of *T&TI* editorial offices). There will be shorter tunnel drives in the Royal Docks, East London.

More tunnelling contracts are due to be awarded in 2011 including the Thames Tunnel between Plumstead and Woolwich.

California and feds support 65-km tunnel

USA

California recommends building a USD 12.7bn tunnel to bring water from the San Francisco Bay, south to the Sacramento-San Joaquin Delta.

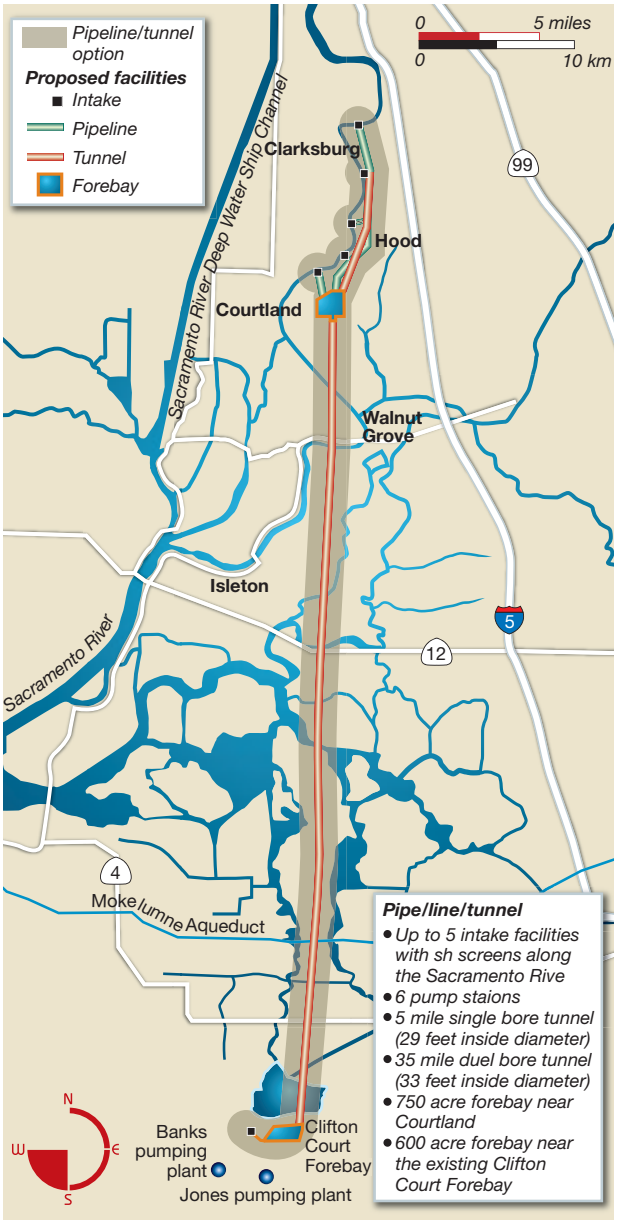
A report issued by the Bay Delta Conservation Plan (BDCP) Steering Committee, a collaboration of state, federal and local agencies, recommends a 5-mile (8km) single bore tunnel, with a 29ft (8.8m) i.d. from the Sacramento River to an intermediate forebay. Another 35-mile (56km) dual bore tunnel with 35ft (10m) i.d. would then connect to a new forebay and pumping plant. Tunnels would run as deep as 150ft (45.7m).

The tunnel option is said to be the best for bringing drinking water to the Central Valley, while protecting the delta's ecosystem. The final size of the tunnel will depend on future analysis of costs versus benefits and further assessment of environmental effects.

A coordinated federal report, issued the same day, calls for the construction of a new water conveyance system.

"After years of drought, growing stress on water supplies, and with the Bay-Delta in full environmental collapse, it has become clear to everyone that the status quo for California's water infrastructure is no longer an option," said Ken Salazar, secretary of the interior.

The tunnel will be paid for by state and federal water contractors. A Public Review Draft should be available for public comment fall 2011.



Alaskan Way bored tunnel bid opening

USA

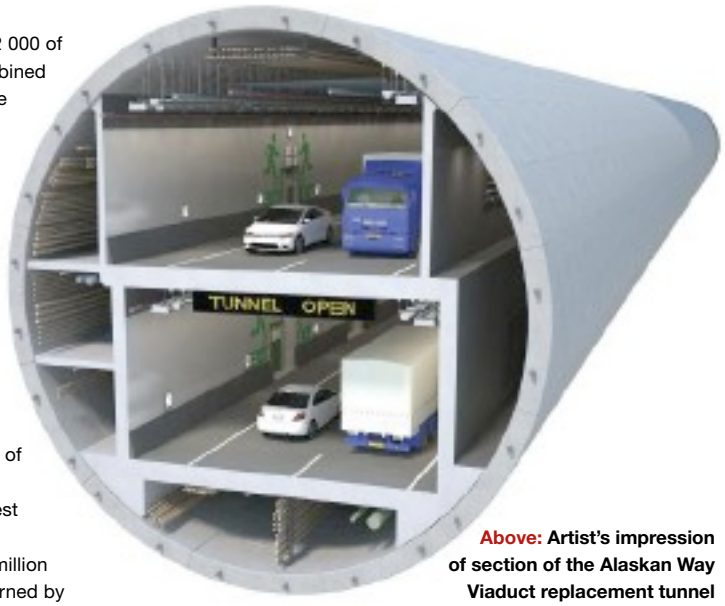
Seattle Tunnel Partners has submitted the apparent best value proposal to design and build the bored tunnel for the Alaskan Way Viaduct replacement, the Washington State Department of Transportation (WSDOT) announced on 9 December.

The joint venture of Dragados USA and Tutor Perini, with subcontractors Frank Coluccio Construction, Mowat Construction; and HNTB Corporation and Intecsa for the design submitted a bid price of USD 1.0897bn, and technical credits totaled 71 577 000, for a combined apparent best-value score of 1 018 123 002.

The Seattle Tunnelling Group, comprising S A Healy, FCC Construccion, Parsons Transportation Group and Halcrow, submitted a bid price of USD 1.088bn with 38 152 000 of technical credits. Its combined apparent best-value score was 1 050 150 002.

"While lowest price is typically the winner, this time we considered both price and the team's approach to schedule, design and other factors," said WSDOT secretary Paula Hammond. "The price from Seattle Tunnel Partners was slightly higher, but our evaluation of their technical approach found it will deliver the best apparent value."

There were up to 100 million technical credits to be earned by each team for overall management, schedule, tunnel roadway clearances, management of tunnelling and ground deformation, and design and construction other than tunnelling.



Above: Artist's impression of section of the Alaskan Way Viaduct replacement tunnel

Major items in the contract are the TBM and the boring; the road within the tunnel; ventilation; fire/life safety and electrical systems; two operations buildings; tunnel settlement mitigation and portal construction. The contract was due for award in late December.

Second contract awarded for Abu Dhabi tunnel

UAE

Italian contractor Impregilo has confirmed that it has been awarded a second contract by Abu Dhabi's Sewerage Services Company (ADSSC) for the construction of a 10km section of a 40km sewer tunnel. The USD 200M award was confirmed on 30 November with the firm beating bidders such as fellow Italian firm Astaldi, Germany's Ed Zublin, UAE-based Lindenberg and French firm Bouygues Batiment International.

The 10km section will have a 7m external diameter with a 5.5m internal diameter. "In addition to the tunnel, the project involves construction of four access shafts to depths of between 60 and 80m, as well as the links to the main tunnel," said the Impregilo statement on the contract, which is expected to take three years to build. Rates of up to 100m per week are expected.

"The project presents significant technical and organisational complexities. It involves simultaneous use of two earth pressure balance tunnel boring machines for pressures up to 8 bars, to bore and simultaneously line the tunnel with precast concrete elements," the statement said.

The contract is the second awarded to Impregilo, which this month (December) starting boring a 15km central section of the sewer worth AED 891M (USD 243M). The award was made in September 2009 and involves three 6.3m diameter EPB TBMs. A further four contracts are also still to be awarded for the remaining sewer section, connecting tunnels and a major pumping station.

Changes for Legacy Way tunnel

AUSTRALIA

The co-ordinator-general of the Queensland Government's Department of Infrastructure and Planning agreed changes to the planned Legacy Way tunnel on 17 December.

The changes included a realignment of the proposed route of the underground toll roads, a relocation of the tunnel control centre and the requirement for a project ventilation station to be buried. This would allow for future expansion of the nearby Mt Coot-tha Botanical Gardens. The cogordinatior-General also killed off plans for a temporary workers' car park. Changes made to Brisbane City Council's spoil conveyor system will also see a 14 000-truckload reduction over the 14-month period of peak construction.

The underground toll roads, part of the South East Queensland Infrastructure Plan and Program (SEQIPP) will link the Inner City Bypass at Kelvin Grove with the Centenary Motorway at Mt Coot-tha.

Stirling Hinchliffe, minister for infrastructure and planning, said, "the requested alignment change will result in operational improvements with easier grades within the tunnels providing more efficient traffic flow."

The co-ordinator-general's full report can be viewed at: http://www.dip.qld.gov.au/resources/project/northern-link-tunnel/northern-link-road-tunnel-cg-report.pdf

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Norwegian road tunnel improvement

NORWAY

The Norwegian roads authority (Statens Vegesen), western region, is seeking contractors to improve the Steinanes Tunnel at the Bortveit power station on the E39 main road in Stord. The site is described as one of the most critical points between two previously improved road sections. Works will consist mainly of back-ripping the existing tunnel, installing new water leakage and frost protection, and also the installation of fire protection and portal improvements.

The contract includes electrical and electronics works at one end of the tunnel portion. Additional work includes work on a large ashlars wall and steel core piling near the tunnel and highway.

Work and materials quanitities listed include 3550m^2 of membrane in an arch, the same area of fire protection, 300m^3 of 'gunite' and 950 rock bolts. Blasting required amounts to 4000m^3 in the tunnel and 11 000m^3 associated with the ashlars wall work.

The site is located in the Bomlo municipality in Hordaland county. The E39 road will continue to be in use, with redirection, throughout the works period.

For further information contact robert.balzer@vegesen.no or to register interest see http://www.doffin.no/Search_Switch.aspx?ID=21892. The tender deadline is 25 January.

Sri Lankan Hydropower project contract awarded

SRI LANKA

China National Electric Equipment Corporation (CNEEC) has won the contract to construct the Broadlands Hydropower Plant on the Kelani River in Sri Lanka.

The USD-82M project requires the construction of an 850m-long diversion tunnel and a 3.5-km headrace tunnel.

Environmental clearance has been granted and construction is expected to begin in early 2011, lasting four years.

The funding for the project has been agreed and will take the form of a series of commercial loans provided by the Industrial and Commercial Bank of China as well as the People's Bank of Sri Lanka.

The 35-MW plant is expected to add 126 GWh to the national grid annually and forms the final piece of the Laxapana cascade system, which totals 350 MW.

The plant also requires a 24m-high and 114m-long concrete dam, and a 19m-high and 48m-long diversion dam.

Right: Kelani River, site of the proposed hydroelectric plant

Ground conditions delay Lake Mead

USA

A second inflow of material at the tunnel face has further delayed the start of tunnelling on Intake No. 3 at Lake Mead, Las Vegas and may affect its alignment.

Contractor Vegas Tunnel Constructors (VTC), a JV of S A Healy and Impregilo and its client, the Southern Nevada Water Authority (SNWA) are working on a contingency plan to deal with geological instabilities.

It is unknown when the 6.36m diameter Herrenknecht TBM, delivered in May 2010, will begin boring the 4.83-km tunnel, and the SNWA confirmed completion has been moved back from 2013 to 2014.

Excavations on the starter tunnel stopped in July when VTC encountered a pocket of loose rock and soil behind the face of the starter tunnel. Following nearly four months of recovery work, the second inflow happened in late October.

VTC was able to install a pre-fabricated temporary bulkhead to contain the material where they were working, about 40ft (12m) from the tunnel face, roughly the same place as the first incident.

"This second inflow demonstrated that the geologic feature, an ancient fault in the rock, is still unstable and will require greater care and effort to surpass than previously anticipated," said Marcus Jensen, director of engineering, SNWA.

"Contingency planning will include the option of bypassing the fault by adjusting the tunnel alignment, if necessary," he said.

News in brief

Bank Station re-tunnel
Plans to refurbish London Underground (LU)'s Bank Station include re-tunnelling the Northern Line to make a more spacious platform and help relieve congestion. LU said the station has shown a huge increase in passenger numbers in recent years—with a 43 per cent rise in customers changing at the station and the number of passengers entering and leaving up by about a third since 2003. LU will need to secure planning permission and a Transport & Works Act Order for work to start in 2015 and finish by 2021.

ARC cancellation allows Penn Station renovation
Redesigning the Long Island Rail Road (LIRR)'s Penn Station concourse had been delayed due to the potential of disruptions while building the Access to the Region's Core (ARC) tunnel, a commuter rail line from New Jersey, which was to terminate at the station. With New Jersey governor Chris Christie's cancellation of the tunnel, LIRR told the *Wall Street Journal* it will issue a solicitation in early 2011 for design proposals. Penn Station is owned by Amtrak and houses the connection of three different railroads with New York City's Subway.

Windsor-Essex Parkway reaches financial close

CANADA

The Windsor Essex Mobility Group (WEMG) has reached financial close and signed a fixed-price contract worth CAD 1.4bn (USD 1.38bn) with the Province of Ontario for the 11km Windsor-Essex Parkway, which includes 1.8km of tunnels.

The concession consists of the design, construction, financing and maintenance of the Parkway, which will link highway 401 in Canada with Interstate 75 in Michigan by bridge, built under another contract. The highway will have three lanes in each direction and will ease road traffic to and from the border, separate local and international travel and eliminate stop-and-go traffic in residential areas.

WEMG key partners include ACS Infrastructure Canada, Acciona Concessions Canada and Fluor Canada. It has agreements in place with local companies, including Hatch Mott MacDonald, Amico Infrastructure, Dillon Consulting, LEA Consulting, Black & McDonald and AMEC.

Steel placement in the Windsor-Essex Parkway, Spring 2010

The Parkway will be delivered using Ontario's alternative financing and procurement delivery model, which transfers most risks associated with designing, constructing and maintaining the Parkway to WEMG.

Beginning in January, WEMG will start design work on the Parkway, engineering survey work and soil investigations. Full construction is expected to start in summer 2011 with completion in 2014.

News in brief

Ottawa should shorten its planned LRT tunnel

An engineering report recommends the City of Ottawa shorten its 3.2km downtown LRT tunnel after rock samples from drilling this summer showed bedrock to be two to 10m deeper than anticipated in one area of the alignment. Engineers recommend the tunnel be cut by 600 to 900m, leaving one of the four planned stops above ground. Shortening the tunnel should not change the expected CAD 2.1bn (USD 2.07bn) cost, which was approved by the City Council in June 2010.

High-speed rail money for Ohio and Wisconsin redirected

USA

The US Department of Transportation announced on 9 December it will redirect some USD 1.195bn of the high-speed rail funds it had originally set aside for Ohio and Wisconsin to other states.

Initially, Wisconsin had been allotted USD 810M for a Madison to Milwaukee corridor, and Ohio USD 400M for its '3C' route—Cincinnati-Columbus-Cleveland.

Governor-elect Scott Walker of Wisconsin and Governor-elect John Kasich of Ohio had both said they'd refuse to spend Recovery Act money on high-speed rail projects in their states, following their early November elections.

California and Florida are to be the biggest recipients of the redirected funding, receiving USD 624M and USD 342M, respectively. Washington, Illinois, New York, Maine, Massachusetts, Vermont, Missouri, Oregon, North Carolina, Iowa and Indiana will all also receive part of the money, as well as Wisconsin, for Amtrak's Chicago-Milwaukee Hiawatha Line.

Transportation secretary Ray LaHood said, "I am pleased that so many other states are enthusiastic about the additional support they are receiving to help bring America's high-speed rail network to life."

The Recovery Act included USD 8bn to launch a national high-speed rail programme.

Finnish finance to continue airport tunnel

FINLAND

The European Investment Bank (EIB) has agreed to lend the Finavia Corp in Helsinki, Finland, EUR 45M (USD 59) in order to assist with the company's share of the Ring Rail Line project in the capital. Other finance for the project is being provided by the Finnish Government and the city authority of Vantaa.

The project is planned to include an 8-km tunnel linking the centre of Vantaa Airport with the rest of the 18-km rail route across the city. The Aviapolis business park will also be served by the line.

The new rail route is listed as a European Union Trans European Transport Network (TEN-T) priority and is also part of the Nordic Triangle to improve rail, road and marine infrastructure from Finland to Sweden.

Construction of the tunnel is already underway but had been halted for two months by concerns over seepage of glycol-sourced contaminants, (officially linked to aircraft de-icing) into the excavation under an airport runway. The levels of harmful substances in the soil were checked by the Institute of Occupational Health and found to be low, but glycol is known to encourage bacterial growth when mixed with oxygen.

Together with Finavia, partners in the project are the Finnish Transport Agency's (FTA) road department and the City of Vantaa with project direction by the FTA's rail department. Finavia maintains Finland's 25 airports and the national air navigation system.

The rail link is designed to speed transport at up to 120 km/h and 10-minute intervals and to reduce road traffic with associated environmental benefits. EIB describes the airport as one of Europe's main gateways to Asia. The loan is one of many by the EIB supporting the European Union strategy for the Baltic Sea Region under the four priorities of sustainable environment, regional prosperity, increased accessibility and attractiveness, safety and security.

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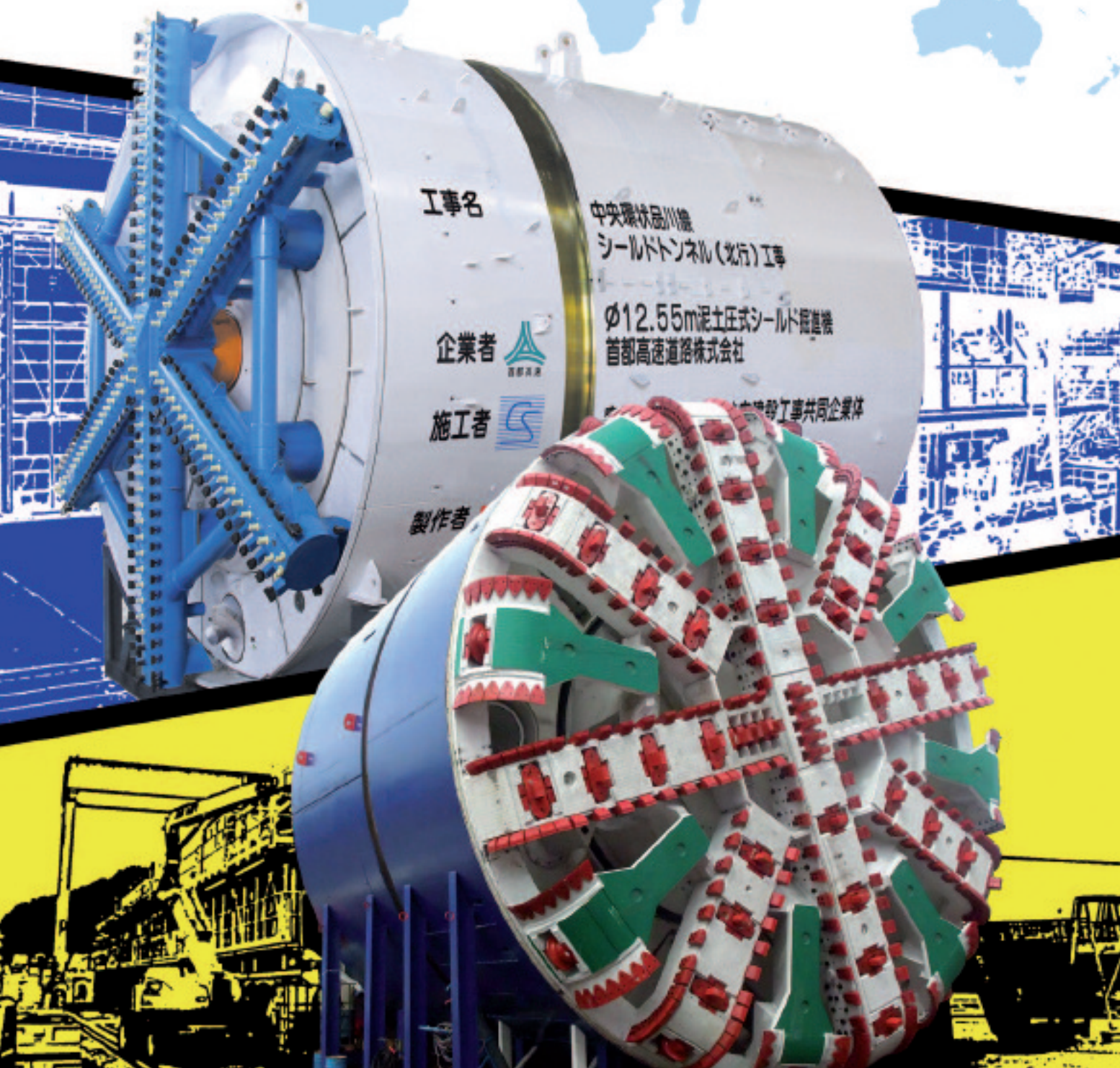
SELI & Kawasaki

THE LEADING TEAM IN EPB TBM TECHNOLOGY



Largest TBM handover

ITALY

The joint venture contracted with constructing a busy section of the A1 highway in Italy has accepted handover the world's largest earth-pressure-balance (EPB) TBM for the Sparvo Tunnel part of the project. The Herrenknecht S-574 EPB TBM has an excavation diameter of 15.62m for a finished internal tunnel diameter of 13.6m to accommodate two lanes and an emergency lane in each tube.

The 2.5km-long, twin-bore (2,494m and 2,431m lengths), Sparvo Tunnel will be part (Lot 7) of the La Quercia-Badia Nuova improvement of the A1 between Bologna and Florence being constructed by Autostrade per l'Italia SpA. The JV contracted to do the work consists of Vianini Lavori, Toto Costruzioni Generali, and Profacta. The TBM owner, Toto Costruzioni Generali, invited top representatives of all concerned companies to the Herrenknecht headquarters in Schwanau to present the machine and explain its functions.

During late December the TBM is being disassembled for the first components to be shipped to Italy in January to meet a tight schedule for site reassembly in February. It will then start tunnelling in a northerly direction in May. It has 12 MW total installed power. The cutterhead, with a torque of 94,793 kNm, carries 78 cutter discs, 216 cutter blades, 24 spoil buckets and a centre 'knife'. It will install 2m-long pre-cast lining segments. The spoil will be removed by covered belt conveyor with an explosion-proof drive.

Lots 6 and 7 of this project are the Variante di Valico stretch between the 3km-long Val de Sambro tunnel (plus another 880m in Lot 5) and Baia Nuova. The client, Autostrade per l'Italia, says that the stretch has required more time to design than expected due to complex geology. This includes clay, argillite and sandstone, and also expected to contain explosive methane in loose ground sections. A new feasibility study had to be carried out and also the design had to accommodate measures passed by the Council of Members in August 2001. Spea is preparing an in-depth environmental report relating to changes to the route of the Sparvo Tunnel between Sasso Marconi and Barberino del Mugello.

The new route is scheduled for opening at the end of 2013 to reduce the travelling time between Bologna and Florence for up to 90,000 vehicles a day.

Above: The world's largest EPB TBM assembled in the Herrenknecht yard at 15.62m diameter and 130m length

National Grid calls for input on undergrounding cables

GREAT BRITAIN

National Grid has started on 15 December its search for outside input on the approach it takes for undergrounding the electricity lines necessary to connect new power generation.

Sectors that have been targeted for this consultation include industry, government, environmental and general public.

Hector Pearson, National Grid stakeholder and policy manager said: "We last reviewed our undergrounding approach in the early 1990s. With a significant amount of new power generation needing to connect to our network in the coming years, including low carbon generators such as nuclear power and wind farms, we believe that now is a good time to review our approach."

He went on to say: "We need to manage the costs of these projects responsibly as these costs will ultimately be paid for by electricity consumers. However, we also need to consider the impact on the local landscape and communities of what we build."

The consultation will last until 16 March 2011.

National Grid says it will consider all feedback received before publishing their revised approach to undergrounding in April.

Contributions to the consultation can be made by registering and completing the questionnaire at: www.nationalgridundergrounding.com

Protests produce HS2 changes

GREAT BRITAIN

Increases to tunnels are among the changes to the proposed England high-speed rail route (HS2) from London to the West Midlands, and eventually on to the North-West.

These were announced by UK transport secretary Philip Hammond on 20 December, as Tunnels & Tunnelling went to press, in a move widely believed to be an attempt to divert growing pubic protest about the route. Many of the changes affect Conservative-held parliamentary constituencies and other influential communities.

The minister's statement said that the changes affect about half of the route, which will be built in two phases: the first from London to Birmingham, and the second from there to the North-West. However, a spur to London's Heathrow Airport may be part of phase two, at least in consultation. High Speed Two (HS2) has been asked to draw up detailed plans for this.

One particularly sensitive area is the route through the Chilterns, but here the changes are relatively small compared to a major cutting planned from Amersham to Wendover. Between Old Amersham and Little Missenden there will be a 150m-long 'green bridge' over the cutting to carry a right-of-way, and between South Heath and Wendover the alignment has been lowered by about 5m and now incorporates a 900m-long 'green tunnel' to pass by South Heath.

The Primrose Hill tunnel in north London is being moved 100m further north to be closer to planned ventilation shaft locations, and it will also be deeper. HS2 will now link directly with HS1.

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Feds offer partial credit for ARC bill

USA

Concerning the USD 271M tab to the Federal Government for work completed on the cancelled ARC tunnel, New Jersey could see USD 128M of the debt credited if it repays the bill in full.

Transportation secretary Ray LaHood wrote to democratic senator Frank Lautenberg of New Jersey saying USD 128M would be credited to the state's Congestion Mitigation Air Quality account once it pays back the full USD 271M, according to a letter dated 14 December obtained by Associated Press.

The Feds are willing to call-off repayment of another USD 22M used for engineering and environmental work on the tunnel before its cancellation.

Governor Chris Christie, who cancelled the tunnel over fears of cost overruns, had untill 24 December deadline to pay or appeal the bill. That has been extended to 10 January.

At the time of press Christie had not announced a decision on the offer though he had hired Washington DC-based law firm Patton Boggs to fight the bill earlier in the month.

Lautenberg, who helped secure federal money for the project and has clashed with Christie over its suspension and cancellation, said he's pleased with the Federal offer.

Hochtief stands firm on ACS bid

GERMANY

Hochtief's board has continued to urge shareholders to not accept an aggressive offer from Actividades de Construccion y Servcios (ACS). Hochtief's executive board and supervisory board called on shareholders to not accept an increased offer from the Spanish company, which just two days prior on 15 December floated an initial bid.

ACS, a major shareholder in Hochtief, had increased its offer to nine ACS shares in exchange for five Hochtief shares, from the original eight shares. Hochtief, in a statement published on 17 December, called the increased offer inadequate, saying it "does not reflect the fundamental value" of the company's stock.

The second ACS offer in 48 hours means shareholders would receive an additional 12.5 per cent per share. The Spanish firm says this bid is 26.5 per cent above a 3-month average price for the shares, while Hochtief argues the bid would leave shareholders out by at least EUR 13 (USD 17) per share.

Earlier in December, ACS' 29.98 per cent holdings in Hochtief were diluted to 27.25 per cent after the German board sought investment from Qatar Holding, which took 9.1 per cent of the firm.

This move upset Hochtief shareholder Southeastern Asset Management, which sold two million shares in Hochtief to ACS on 15 December. Under German market rules, a 30 per cent holding would allow ACS to purchase the majority of Hochtief stock in the markets, avoiding the need for a hostile takeover.

News in brief

EIB funds Stockholm rail
The European Investment Bank (EIB) announced it will provide loans up to EUR 600M (USD 785M) to the Citybanan commuter train project in Stockholm, which will include 6km of tunnel, two underground stations and a railway bridge.

Marmaray Project tender deadline extended
Turkey's Ministry of Transportation (DLH) has extended the deadline for submissions for the Marmary Project's Contract CR3 to 28 February 2011. CR3 concerns civil, electric and mechanical systems on the Gebze to Halkali commuter rail, which includes tunnels to and from an immersed tube tunnel under the Bosphorus.

Cat Bucyrus integration
Caterpillar has announced that Steve Fisher is to become vice-president with responsibility for integrating Bucyrus International. The closing date for the acquisition is expected in mid-2011, subject to regulatory approvals, closing conditions and Bucyrus shareholder approval. Fisher is currently Caterpillar's vice-president for the Remanufacturing and Components Division. Gregory Folley will take over Fisher's position from Corporate Human Resources.

Moves at Normet
Rick Kraft, principal of Normet USA, has taken a senior project manager position at the global level. Also, as of 1 January, Mark Mudlin has joined Normet Americas as sales manager – mining. His previous employment includes Asamera Minerals, Barrick Goldstrike Mines, Anglogold, and he spent the last eight years with BASF as a technical sales specialist.

Finance for Eurasia Tunnel

TURKEY

The European Investment Bank (EIB) has agreed to lend EUR 250M (USD 328M) (subject to appraisals) to the Ministry of Transportation department of the Republic of Turkey (DLH), for the Eurasia Tunnel project, or the Istanbul Strait Road Tunnel Crossing, to give it its full name.

The PPP project, to be appraised at around EUR 768M (USD 1008M) total value, covers the design, financing, construction, operation and maintenance of the road tunnel. The crossing will have a total length, in three sections, of 14.6km.

The central submarine duplex tunnel section, 5.4km long, will be operated under a 30.5 year-long concession, while the non-tunnel road sections at each end will be returned to the public authorities on construction completion. The concession period includes four years, seven months for construction. After widespread international interest, a Turkish-Korean jv (TKJV, consisting of Yapi Merkezi of Turkey and the SKEC consortium of South Korea consisting of Samwhan, Hansin, Namkwang and Kukdong) was awarded the concession at the end of 2008, and the Build-Operate-Transfer (BOT) contract is now being finalised for signature. It will be the biggest project in Turkey operated under BOT. The EIB has stated procurement procedures to be satisfactory.

Under European Directives the project will be subject to a full Environmental Impact Statement including public consultation.

According to Istanbul Chamber of Commerce records, the Eurasia Tunnel Operation Construction and Investment Joint Stock Company (ATAS) topped the list of the biggest 10 companies set up with foreign capital participation in 2009.

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Chinese consortium wins world beating immersed tube tunnel contract

HONG KONG-ZHUHAI-MACAO BRIDGE

China Communications Construction Company has been announced as the winner of the design and build contract for the 6.7km long, 14m internal dia. immersed tube tunnel section of the 29.6km Hong Kong-Zhuhai-Guangdong bridge crossing.

Client the Hong Kong-Zhuhai-Macao Bridge Authority announced that it had completed the tender evaluation on 17 November. The organisation is the managing body for the project and includes the government of Guangdong Province, and governments of the Hong Kong and Macao Special Administrative Regions.

Members of the successful CCCC joint venture are AECOM Asia Company, Shanghai Urban Construction (Group), China Highway Planning and Design Institute, COWI A/S, Shanghai Tunnel Engineering & Rail Transit Design and Research Institute and CCCC Fourth Harbor Engineering Investigation and Design Institute. Construction is set to begin imminently for completion in 2016.

The proposed crossing will link the Hong Kong Special Administrative Region (HKSAR), with Zhuhai City in Guangdong Province and the Macao Special Administrative Region (Macao SAR). It consists of a main bridge over the mainland waters together with the tunnel, artificial islands and link roads within all three territories.

The purpose of the connection is to reduce the travel time between Hong Kong, the region of Pearl River West in mainland China and Macao and at the same time establish a new land transport link between the east and west coasts of the Pearl River. The connection will reduce the commuting distance between the Pearl River West region and Hong Kong by four hours making the journey down to just three hours. The regional governments expect that this will make the mainland more attractive to external investment as well as enhancing Hong Kong's position as a trading and logistics hub.

Above: The link with switch from the elevated bridge to the immersed tube tunnel via an artificial island

"The tunnel will become the longest immersed tube tunnel in the world on completion," said the government of HKSAR Highways Department in a statement announcing the tender evaluation. Longest to date is the Denmark-Sweden connection the Oresund Tunnel with a 3.51km immersed tube section.

The tunnel itself will be located on the Hong Kong side of the crossing, taking the dual three-lane road under the busy navigation route of the Lingding Channel. Two artificial islands must also be constructed at either end of the tunnel. "Since the artificial islands and tunnel will be constructed in sea environment, it is anticipated that the technical difficulties and challenges will be of world-class level, taking into account the long distance ventilation and safety design, prefabrication and marine transportation of huge pipe segments, joining pipe segments under high water pressure as well as construction of the west and east artificial islands," says the Highways Department.

The eastern artificial island will sit just within the Hong Kong SAR boundary. From here the remaining road is expected to be carried over the water using a series of cable stayed bridges.

Preliminary construction work has already gotten underway with the reclamation works for Zhuhai-Macao boundary crossing facilities, including necessary reclamation works for the west landing point and the toll plaza for the main bridge, commencing in December 2009.

Cost estimates for the scheme are still under review but it is understood that the project cost will be shared according to the principle of equalization of benefit to cost ratio. This means that Hong Kong will bear 50.2 per cent of the cost, Guangdong 35.1 per cent and Macao 14.7 per cent. The project authority anticipates that 42 per cent of the cost will be financed from the government contributions, with the remaining 58 per cent in syndicated loans.

Financial institutions were invited to express interest in October 2008 and 34 responses were received but government guarantees may be required. Early estimates place the total construction cost at USD 9bn.

The link is expected to carry both passenger and freight traffic when it opens in 2016 and daily traffic volumes are forecast at up to 14,000 vehicles per day. By 2035, the daily traffic volume is expected to have increased to a maximum of 49,200 vehicles.

Initially a rail link was considered as part of the proposals but the authorities discovered that the incorporation of railways into the bridge would not significantly increase the passenger flow volume, but would have a major increase on the project cost.

This is mainly to do with the complexities of adjusting the gradient to ensure that it can carry a railway. In view of different railway designs in Hong Kong and the Chinese mainland, it would also incur additional cost to provide the through train service.

Bernadette Redfern

T&T 2011 photo competition

Get snapping as *T&T* is proud to announce the return of the photo competition

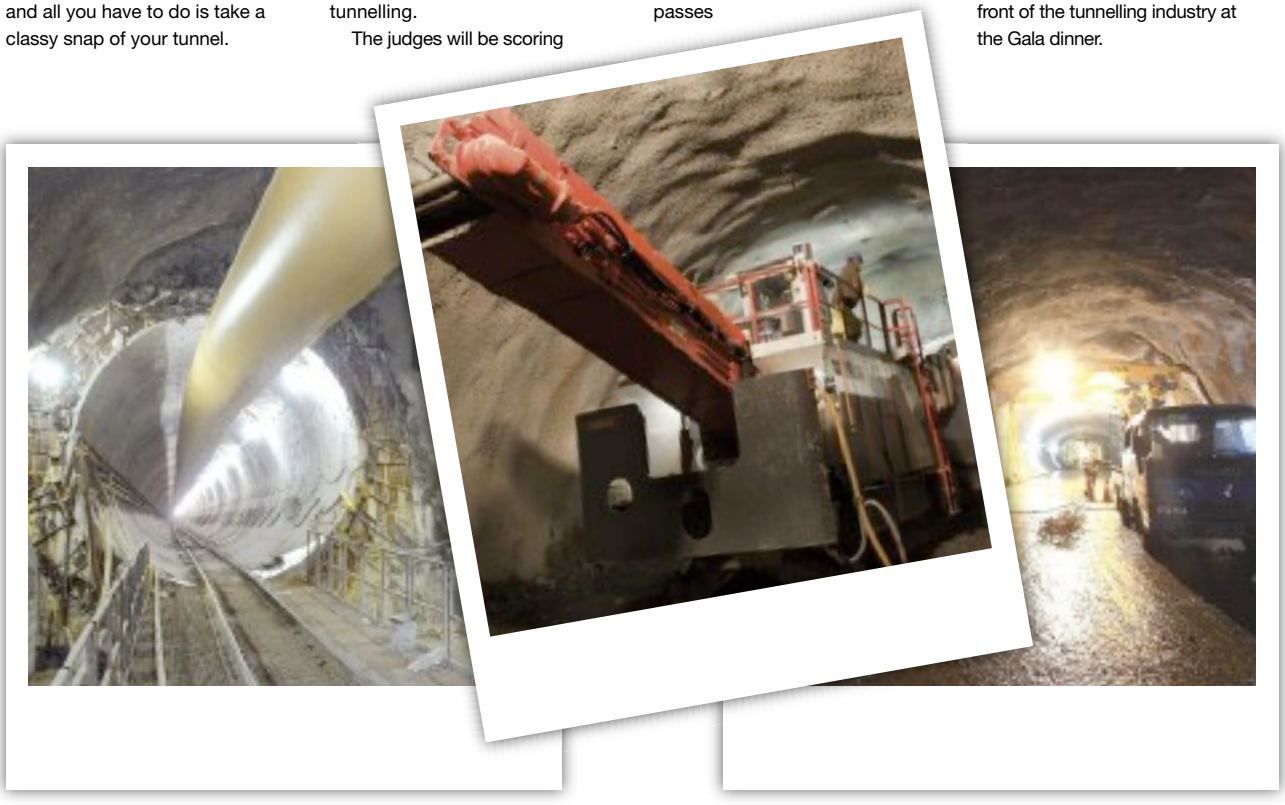
It is time to learn how to tell your aperture from your exposure! *T&T* has relaunched its photo competition after several years in retirement. Once again we are giving you the chance to win the latest in digital camera technology and all you have to do is take a classy snap of your tunnel.

Capture the moment that defines a tunnel project. Be it contractors knee deep in mud and concrete or the glossy finish of a newly laid segment. We are looking for the photo that can reveal the true nature of tunnelling.

The judges will be scoring on the technical quality of the shot and the moment it captures.

The closing date for entries is 1 July and the three short listed entrants will be announced in the August issue of *T&TI*. The final three will be given free passes to the T&T Conference and Exhibition being held in Germany this Autumn and will be seated on the T&T table at the Awards Gala dinner on the first night.

The winner will be presented with his or her award and prize in front of the tunnelling industry at the Gala dinner.



Top ten tips

Competition judge Nick Kozak gives his top tips to taking the perfect photo:

1. Shoot, shoot, shoot as much as you can.
2. Think before you shoot; what are you trying to capture?
3. Composition should be a priority.
4. Get closer - Robert Capa said; "If your pictures aren't good enough, you aren't close enough."
5. Edit, edit, edit, upload and sift through your photographs regularly.
6. Be your own critic; learn to identify what works and what doesn't in your photos.
7. Look, look, look at others' photographs, both amateur and professional.
8. Observe the world through an imaginary lens, even when you're not photographing.
9. Show your photographs to others to get feedback.
10. Have fun, get a kick out of photography, it will show in your work.

Win

The winner of the *T&T* 2011 photo competition will receive a digital SLR camera with a full range of accessories. Full details to follow.

The final three short listed by the judges will win free passes to the *T&T* Conference and Exhibition being held in Germany in the Autumn and will win seats at the *T&T* table at the Awards dinner.

Entry is free. Closing date is 1 July. Terms and conditions apply.

The judges

Nick Kozak – Nick is an experienced photographer based in Toronto, Canada who specialises in disaster and construction photography and has recently returned from photographing the earthquakes and aftermath in Haiti.

David Vintiner – David is an accomplished photographer based in London, England. David's clean, understated images have been acquired and exhibited by the National Portrait Gallery.

Henrik Williams – Henrik is creative director at *T&T* publisher Progressive Media. He has more than 20 years' experience in publishing and is responsible for managing all aspects of art and design within Progressive.

Jon Young – As the editor of *T&TI* Jon has to sift through hundreds of tunnel photos in an attempt to sort the wheat from the chaff.

Submit your entries to photo2011@tunnelsandtunnelling.com

Brisbane, urban capital of Queensland

Australia drives for productivity

Record levels of government investment in infrastructure continues the tunnelling boom in Australia as the networks creak with the strain of growing industrial requirements and the demands of a highly urbanised population, Alex Conacher reports

In times of recession, economic wisdom suggests that strong and confident investment is the best recourse. This, of course, also depends upon the exercise of fiscal discipline during the fat years to enable the liberation of resources during the lean.

As the years of plenty were ending, the centre-right coalition government ceded control of Australia in 2007 to the centre-left Labor Party under the premiership of Kevin Rudd. The result was the announcement of a number of spending programs designed to support the economy during recession and invest in future productivity. Infrastructure was identified as a key area of interest and the Government of Australia compiled the nation's first audit of economic infrastructure.

"As one of the most urbanised nations in the world, Australia's future economic success will largely depend on having sustainable, well-planned and productive cities. Better urban infrastructure, particularly with respect to public transport, will be crucial to achieving this outcome. Without this type of investment, the cost of traffic congestion will more than double to AUD 20bn [(USD 19.83bn)] by 2020," said Anthony Albanese, minister for Infrastructure and Transport.

The Nation Building Program is one of these spending initiatives. Through this short-term, high-value scheme, the Government of Australia is investing AUD 36.9bn (USD 36.6bn) in road and rail infrastructure over the 6-year period between the financial years 2008-2009 and 2013-2014. This is claimed to be an 'unprecedented investment by a Commonwealth government in land transport' and is intended to end what the Rudd government described as the '10-year neglect'.

The states each have their own initiatives for infrastructure investment. New South Wales has the State Infrastructure Strategy, South Australia has the Strategic Infrastructure Plan, Tasmania has the Tasmanian Infrastructure Strategy, Victoria has the Victorian Transport Plan and Western Australia has several more specific ventures such as the Main Roads Project. Queensland, however, deserves a special mention.

Brisbane in Queensland is a particular hotspot of tunnelling activity. With projects such as the Brisbane Airport Link, the North-South Bypass Tunnel, the Northern Link Tunnel, the Clem 7 and Cross River Rail to name a few, it is the jewel of the

nation as far as the tunnelling industry is concerned and it is not just the city itself that is investing, the state's level of expenditure is staggering.

The South East Queensland Infrastructure Plan and Program (SEQIPP) is one of the regional plans for public investment in the infrastructure network. Launched in 2005, this project is operated by the Department of Infrastructure and Planning of the Government of Queensland. It currently runs from 2010-2031, being assessed and adapted on a yearly basis. It should provide AUD 134bn (USD 133.05bn) in infrastructure funding by 2031 of which AUD 97.7bn (USD 96.5bn) will be dedicated to transport, AUD 5.4bn (USD 5.33bn) to energy and AUD 1.5bn (USD 1.48bn) to water projects. Some AUD 16bn (USD 15.81bn) has already been spent on projects completed under the scheme. It will support 930 000 jobs by its final year.

Industrial Queensland

Queensland is a major exporter of coal, even claiming to be the largest exporter of coal by sea routes in the world, and produced significantly more than the other states. It is recognised as firmly in the national interest to support this industry. In the economic year 1996-1997, Queensland transported around 90 million tonnes of coal by rail. Some 12 years later, in the year 2008-2009, more than 170 million tonnes were transported.

The demand for coal rides over the global financial crisis, with demand from the rapidly expanding economies of India and China leading the way, with steel production as the industry accounting for approximately 71 per cent of exports.

The greater part of Queensland's coal comes from one of three coal fields or 'basins', the Bowen Basin is this dominant basin. The two almost neglected basins are the Surat and the Galilee. The Holy Grail for the Queensland coal industry would be the connection of these sites with mine-to-port rail networks.

The rail network of South East Queensland is at capacity, however, due to the overloaded hub that is the capital, Brisbane. One solution to this, a tunnel crossing of the capacity-choke that is Brisbane River, is currently in the detailed feasibility phase (see page 22 for feature on Cross River Rail). This is just one of many projects that are currently buoying the tunnelling industry 'down under'.

Beyond Brisbane

Tunnelling in Australia is, of course, not limited to Brisbane. The Adelaide Desalination Project will involve 20km of underground pipeline. The project cost is AUD 1.83bn (USD 1.81bn). An anticipated 650,000m^3 of spoil will be produced and 26,000m^3 of concrete will be used as well as 1780t of steel. Some 100 billion litres of desalinated water will be transported from Port Stanvac to the Happy Valley water treatment storage area every year, accounting for half of the water supply for Adelaide.

The Northern Sewerage project in Melbourne finished excavation works earlier this year on a 700m, TBM-excavated tunnel from Newlands Road to Carr Street. This represented the end of Stage 2 works with remaining tunnel and shaft lining set to continue until early 2011. Total pipe works will stretch for 13km. John Holland was awarded the AUD-301M (USD-297.91M) contract for the first stage and the AUD-171M (USD-169.24M) contract for the second stage. Completion is anticipated for 2012.

The Main Sewer Replacement project in Melbourne (see *T&TI* June 2010, page 27) to replace a 2.3km stretch of the 120-year-old original Melbourne sewer has had to contend with difficult geological conditions in the form of soft, ultra-silty clay. Excavation by an AUD 5M (USD 4.2M), 3m Lovat EPB TBM bored a 2.4m internal diameter tunnel at a gradient of 1:750 to house the 1.8m internal diameter glassfibre reinforced plastic pipe. Bore progress has been lower than expected for much of the drive, but the TBM was launched six months early as a precaution against the difficult ground. The drive towards the Yarra River, ironically, yielded hard basalt. Completion is scheduled for 2012.

Victoria's Wonthaggi Desalination Plant will be the largest in Australia upon completion in 2011. Construction started in 2009 on the AUD-3.5bn (USD-3.5bn) project being carried out by the AquaSure consortium, which consists of Degremont, Macquarie Capital, and Thiess in a public-private partnership (PPP). This project has seen strong public disapproval, including a 3000 signature strong petition submitted to the Victoria Parliament in 2009. Completion is expected by the end of 2011.

Above: **A Lovat EPB TBM used for the Main Sewer Replacement Project in Melbourne**

BOMBELA

GAUTRAIN SITE DEMOBILIZATION

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

Refurbished PAUS Dumper 10000A 20t payload
interchangeable with Concrete mixer CIFA

Refurbished Shotcrete Robot PUTZMEISTER: Model PM 407

Refurbished Shotcrete Robot PUTZMEISTER: Model PM 500

Refurbished NORMET Himec 9915 B.A

LIEBHERR Tower Cranes 280 EC-H 12

For more information please contact:
Nilton Barreira (011 997 8414 / 078 804 3039)
nilton.barreira@bombelacjv.com

GAUTRAIN
FOR PEOPLE ON THE MOVE

Progress on Brisbane's trio of road projects

A year and a half away from its scheduled delivery, tunnelling for Brisbane's Airport Link and related projects is on track—with a little help from revising the alignment, Nicole Robinson finds

Brisbane is Australia's fastest growing metropolitan region, according to the Queensland Government, which expects the population of the South East Queensland region to grow from 2.8M to 4.4M from 2006 to 2031. It's one of the main drivers behind a massive road infrastructure project the state introduced in 2005 to connect the city with the airport and northern suburbs.

The Airport Link, Northern Busway (Windsor to Kedron) and Airport Roundabout Upgrade projects are being delivered together in a single design and build contract. BrisConnections, consisting of Macquarie Capital Group, Thiess, John Holland, Arup and PB, was awarded the contract worth AUD 4.8bn (USD 4.8bn) in May 2008. It is to finance, design, build and operate the Airport Link toll road for a period of 45 years, while the Northern Busway and the Airport Roundabout Upgrade will both be handed back to the state after construction is completed in mid 2012.

A joint venture of Thiess John Holland (TJH) has been contracted for design and construction on the projects, including two separate tunnels: one for the 6.7km Airport Link and one of about 1.5km for the Windsor to Kedron section of the Northern Busway extension (see side block). The Queensland government planned the two projects in conjunction because they share a corridor between suburbs Bowen Hills and Kedron. Once completed, the Airport Link and Northern Busway combined should reduce traffic on the major thoroughfare of Lutwyche Road by up to 40 per cent.

TJH is also building the 750m flyover bridge and 'fast-diamond' intersection that will replace the airport roundabout in the contract's third project, which opened in November 2010, a year early.

These three projects to accommodate potential population growth are hindered by the already densely populated north side suburbs. "There are 31 000 households along the project alignment, and 8000 of these residents are living next to, or within close proximity to, the nine major worksites we have operating across Brisbane," says Gordon Ralph, Thiess John Holland project director.

After a number of breakthroughs this year, BrisConnections announced in December that work is 60 per cent complete and on track to finish as scheduled, despite the pressures to reduce community impact during construction, and the discovery of weaker ground requiring adjustments to the Airport Link project.

Airport Link alignment

The 6.7km toll road will be primarily underground and will allow drivers travelling from the city to the airport to avoid up to 18 sets of traffic lights. The alignment was based on three surface connections to (from south to northeast) the suburbs of Bowen Hills, Kedron and Toombul.

Three-lane twin tunnels are being constructed in hard rock using roadheaders between Bowen Hills and Kedron. Two-lane twin tunnels are being excavated by EPB TBMs from Lutwyche to Toombul where ground conditions are predominantly clays and siltstones. In total more than 11km of tunnel and ramps will be constructed for the Airport Link portion of the project, requiring up to 17 roadheaders and two 12.48m diameter Herrenknecht EPB machines with some cut-and-cover work.

BrisConnections adjusted the alignment to reduce grades and to take advantage of the Brisbane Tuff that underlies the alluvial soils present throughout the northern suburbs, according to a paper presented at WTC in Vancouver by representatives of the concessionaire. This would help reduce the risk of ground surface settlement. Revisions added the mid tunnel access shaft at Truro Street, extended the TBM excavation and moved the TBMs' launch box from Kedron to Kalinga Park in Toombul.

Moving the location of the TBM launch avoided interference with a local high school and emergency services in the area, however it introduced other issues, as the park is prone to flooding.

"The challenging ground conditions in the area, comprising mostly of soft clays, meant we had to pump 350t of bentonite into the ground to stabilise it prior to excavation," says Ralph. "Enormous

Below: **The October 2010 breakthrough by an Aker Wirth roadheader T3.20**

Airport Link and Northern Busway tunnels combined

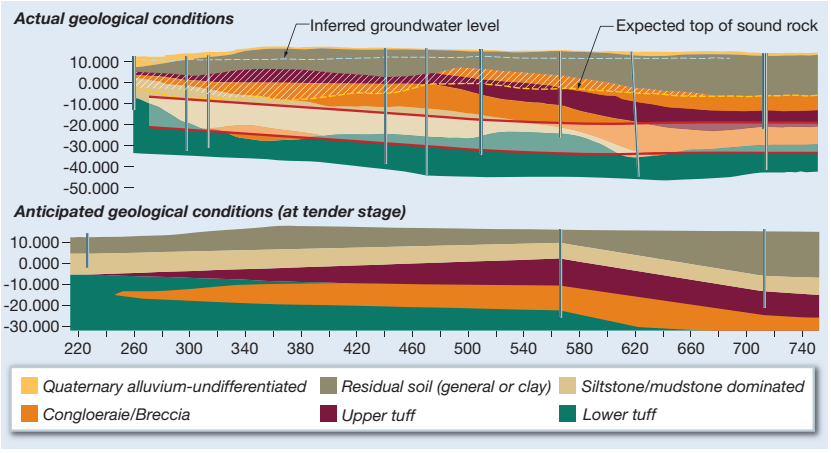
- Roadheader tunnelling: Approx. 8.7km
- TBM tunnelling: Approx. 4km
- Cut-and-cover: Approx. 2.3km

volumes of concrete have been used during excavation and construction, with more than 12 500 cubic metres for completion of diaphragm support walls alone."

"Adding to this complexity is the surrounding Toombul flood plain on which the launch box is constructed, requiring a flood wall to be built around the entire perimeter for protection in the event of a 1-in-100-year flood," he explains.

Revising the alignment also changed the Kedron connection from a surface arrangement done by cut and cover to a network of underground tunnels and ramps built by roadheaders. Two cavern junctions with a maximum span in excess of 25m would be built to link the two tubes of the mail tunnel with the entry and exit ramps.

Generally, geology in the project area is mainly regionally metamorphosed rocks, including hardened shales, greywackes and quartzites. At Kedron, the anticipated strata ranged from Brisbane Tuff at the cavern invert (high strength) and crown (low-to-high strength). In between investigation data suggested intersecting sediments and tuff, overlain by highly weathered material and residual soils. Above the crown the low strength Tingalpa Formation was predicted.



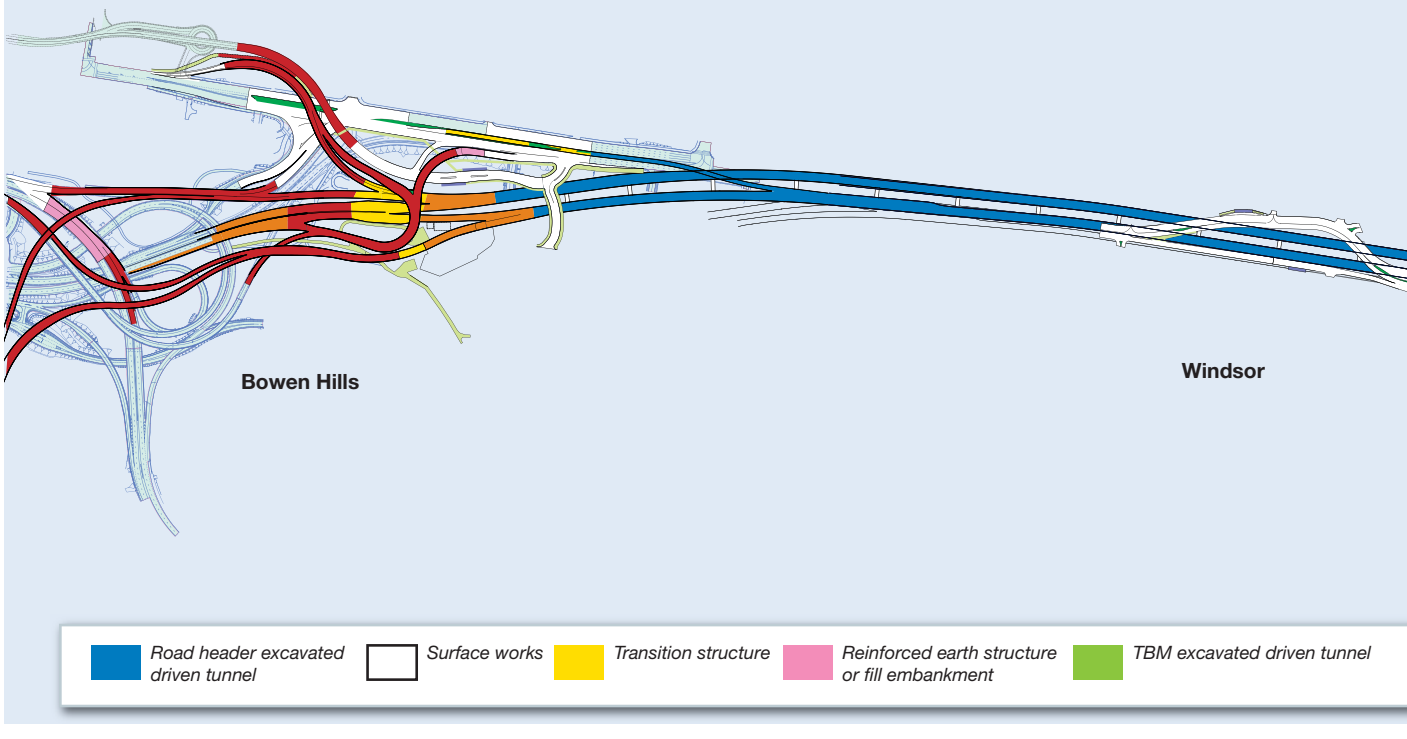
Above: **Fig. 1: Anticipated and actual ground conditions for the Airport Link**
Below: **Fig. 2: Map of the tunneldrive alignments and interconnections**

Additional site investigation found the Brisbane Tuff to be present, but to a lesser extent and quality than anticipated (Figure 1). Besides making excavation more difficult than expected, the new-found geology would require a heavier, more robust support than in the initial design, which would also add delays to the schedule.

In July 2009 TJH sought and received permission from the Queensland government in late 2009 to sink an extra access shaft on Rose Street in Wooloowin, measuring 42m deep and 15m in diameter. This shaft allowed roadheader excavation of the east and west caverns to complete before the TBMs arrived from the launch site at Kalinga Park, as it provided a total of three extra work fronts to overcome any delays.

The consultant hired by the Queensland government to review TJH's application to change plans said that normal levels of site investigation for the size of project had been performed prior to the start of the job, (*T&TI* November 2009, p9).

Revising the alignment had an impact on other aspects of the Airport Link's construction. Some of the proposed traditional hard rock tunnelling for the ramps has instead used a slower and more involved NATM approach, according to the BrisConnections WTC paper.



Tunnelling

Despite earlier fears of delays, Airport Link completion is on track. Tunnelling started in March 2009 with the first roadheader—of what would eventually be 17—excavating from Truro Street, south to Bowen Hills. Roadheader excavation varies to depths as much as 35m underground, and is being used for entry and exit ramps, as well.

Ground conditions are primarily Neranleigh Fernvale rock, unique to the Brisbane area. Cutting heads feature up to 72 picks for hard rock and 57 for soft rock. On average the roadheaders being used on the project weigh 135t and measure 18m in length. Manufacturers have included Aker Wirth, Sandvik and Mitsui.

In June 2010 roadheaders from the Bowen Hills and Truro Street sites met in the northbound Airport Link tunnel, as the project's first breakthrough. By end of November, roadheaders had met in the southbound tunnel as well. BrisConnections estimates permanent concrete lining of both tunnels should be complete by early 2011, while back-end work such as drainage and smoke-duct installation will continue into the year.

North of the Truro Street site, roadheader excavation in the northbound and southbound mainline tunnels is still operating, 24 hours a day. Roadheader excavation on Kedron exit and entry ramps has completed where cut-and-cover construction will take over on the surface.

Two Herrenknecht EPB machines are each boring 2.5km of twin tunnels from Toombul to Lutwyche at various depths up to 55m from the surface. The biggest TBMs ever to work in Australia, according to BrisConnections, each AUD 45M machine was assembled inside a 105m long x 35m wide x 22m deep launch box at Kalinga Park. Two 160-t cranes and three 40-t cranes were required to lower 250 separate components for the 3600t machines. Each 12.48m- diameter cutterhead, carrying 73, 17-in cutter wheels made of hardened steel, weighed 220t alone.

"Because the machines are 195m long they have to be launched in two stages. Once 'Rocksy' and 'Sandy' have excavated 130m they will stop for six weeks so the rear of the machine can be assembled," Ralph explains.

The first machine, 'Rocksy', arrived in Brisbane in November 2009 from Germany and started on the eastbound tunnel in July 2010. 'Sandy' arrived in April and started tunnelling in August for the westbound line. 'Rocksy' had progressed 70m in the eastbound tunnel when 'Sandy' started.

The TBMs are installing a steel-fibre-reinforced precast segmental lining in a 9+1 configuration, with an internal diameter of 11.4m. Segments have been produced at a casting facility in nearby Eagle Farm.

BrisConnections expects more 1.1 million tonnes of spoil will be generated by the TBMs. TJH is running a 1.8km-long spoil conveyor belt that travels from the Kalinga worksite to a purpose-built spoil handling facility adjacent to an arterial road network. This removed approximately 80 000 truck journeys from nearby residential streets.

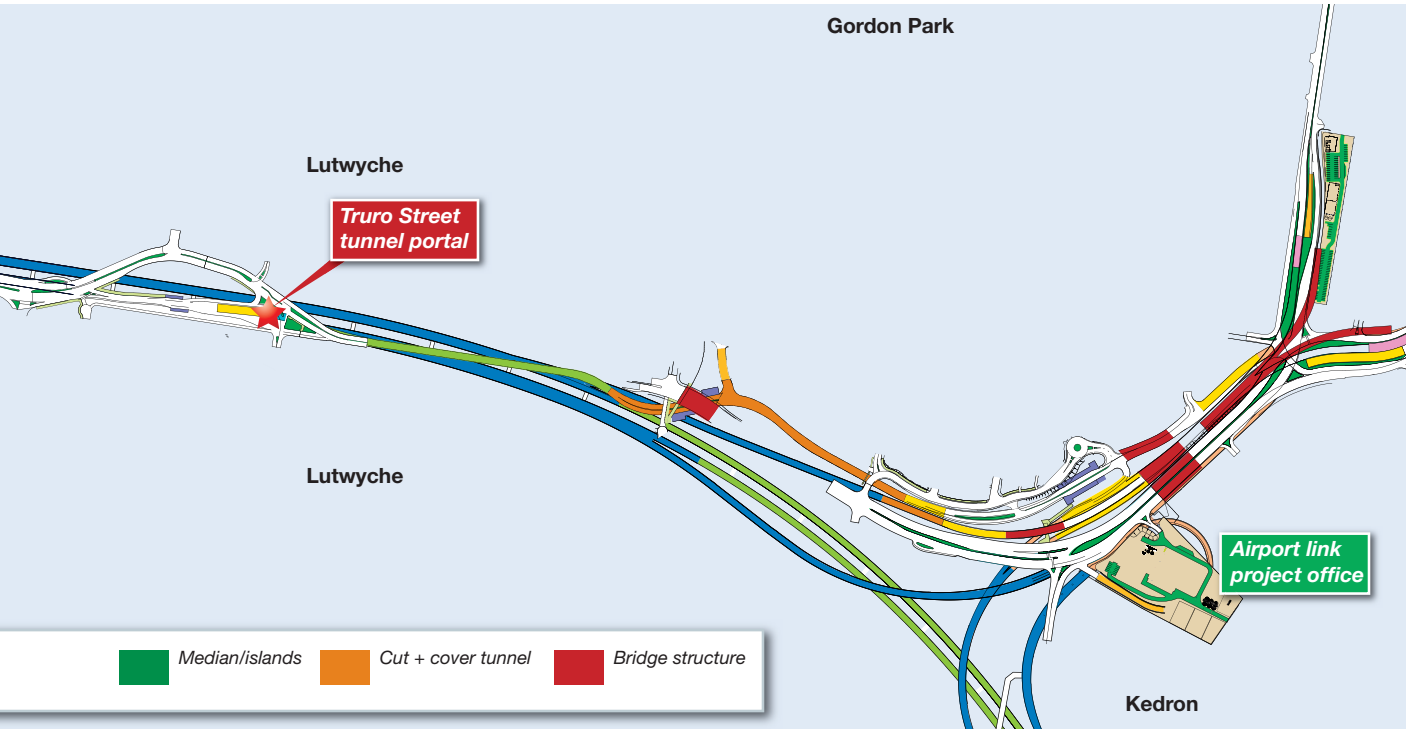
"We understand the construction activities inconvenience and impact some residents," says Ralph. As the Airport Link project nears completion next year, Kalinga Park will be reinstated and returned to the community with enhanced barbecue facilities, waterways and cycle paths.

Northern Busway (Windsor to Kedron)

The Northern Busway will connect Windsor to Kedron along the Lutwyche Road corridor with a 3km 2-lane, 2-way, bus-only road. It will run underground for approximately 1.5km between Truro Street, Windsor and Sadlier Street, Kedron.

Tunnelling for the Northern Busway and is being completed by roadheaders for approximately 500m from Truro Street to the new, surface level Lutwyche Busway Station. The remaining kilometre will be constructed by cut and cover, surfacing at Kedron Brook Busway Station, continuing underground and resurfacing at Sadlier Street.

Roadheaders started in December 2009 and saw a breakthrough in October 2010, having excavated approximately 57 000 cubic metres of rock and soil.



Cross River Rail: Access to Queensland's core

South East Queensland's entire rail network is capacity-capped by its reliance on passage over a single bridge at the hub of the network in Brisbane. The answer is to build a rail tunnel with passenger capacity equivalent to a 30-lane motorway, Alex Conacher reports

Brisbane is a city of humid, sub-tropical summers and dry winters that rarely drop below 10°C. Lightning frequently shatters the skyline and rain falls for one day in three across the year. The city is divided by the river that bares its name and, as the capital of Queensland, it is home to approximately three million people.

The highly urbanised population structure of Australia makes the nation particularly dependent upon its cities. The upside of this is: if you or your business is in a city, you are looked after. The downside is that everything has to come through a densely populated and developed area. Conscious of this and an increasing population, Australia has been investing heavily in infrastructure development programs in recent years as a governmental priority (see Australia drives for productivity, page 16).

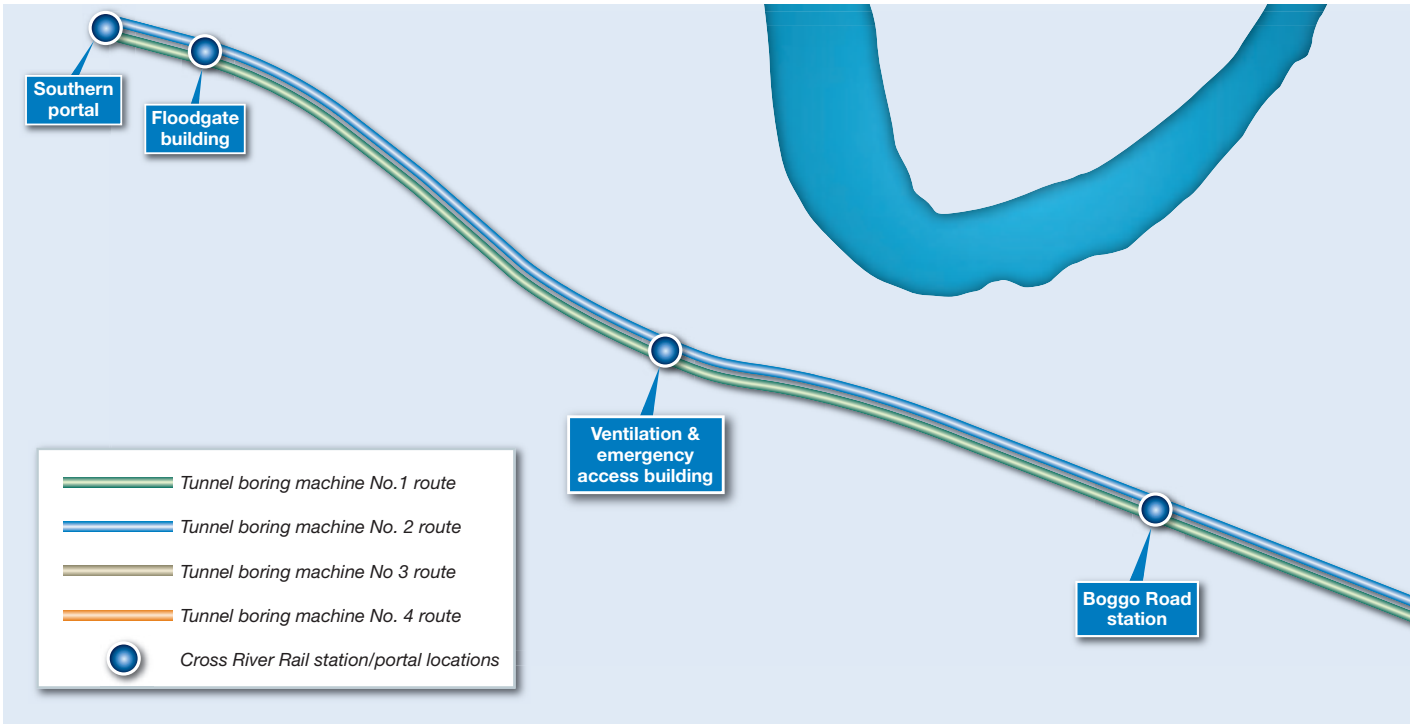
Need and planning

The Merivale Bridge that spans the Brisbane River is the bottleneck of the entire South East Queensland rail network. Already at capacity, further train services passing north to south or vice versa must for the moment remain amongst the sweaty fantasies of transport officials. That is, unless another river crossing can be constructed.

By 2031 the problem will be worse. It is anticipated that the population of Brisbane will be in the region of 4.4 million and the number of workers moving to the region will also increase. On top of this, industrial freight looks to be ever increasing. The year 2031 also marks the end of the counter-measure, the South East Queensland Infrastructure Plan and Program 2010-2031 (SEQIPP). This AUD-134bn (USD-131bn) project, which was first released in 2005 and updated annually, will see a total of AUD 97.7bn (USD 95.5bn) spent on transport by 2031. It is the largest infrastructure plan in the country and is expected to finance almost a million jobs by the time it is concluded.

SEQIPP, along with infrastructure projects from each of the states stands alongside the Government of Australia's Nation Building Program (NBP). The government is pumping AUD 37bn (USD 36.2bn) into infrastructure for the period 2008-2014 through the NBP alone.

"As a result of the record investment



we're making and the sweeping reforms we're implementing, this century could well be another 'golden age' for rail," announced Anthony Albanese, minister for Infrastructure, Transport, Regional Development and Local Government, and Lindsay Tanner, minister for Finance and Deregulation in a joint press statement.

From this background of heavy local and national government investment, the Cross River Rail project was born. Currently in the detailed feasibility phase, SEQIPP lists the funding granted for this stage as totalling AUD 25M (USD 24.5M), of which one-sixth is provided by the regional government and the remaining by the national government.

Civils consultancy for the project is being handled by an integrated joint venture team consisting of Aecom, Hassel and SKM Aurecon, which was appointed in December 2009.

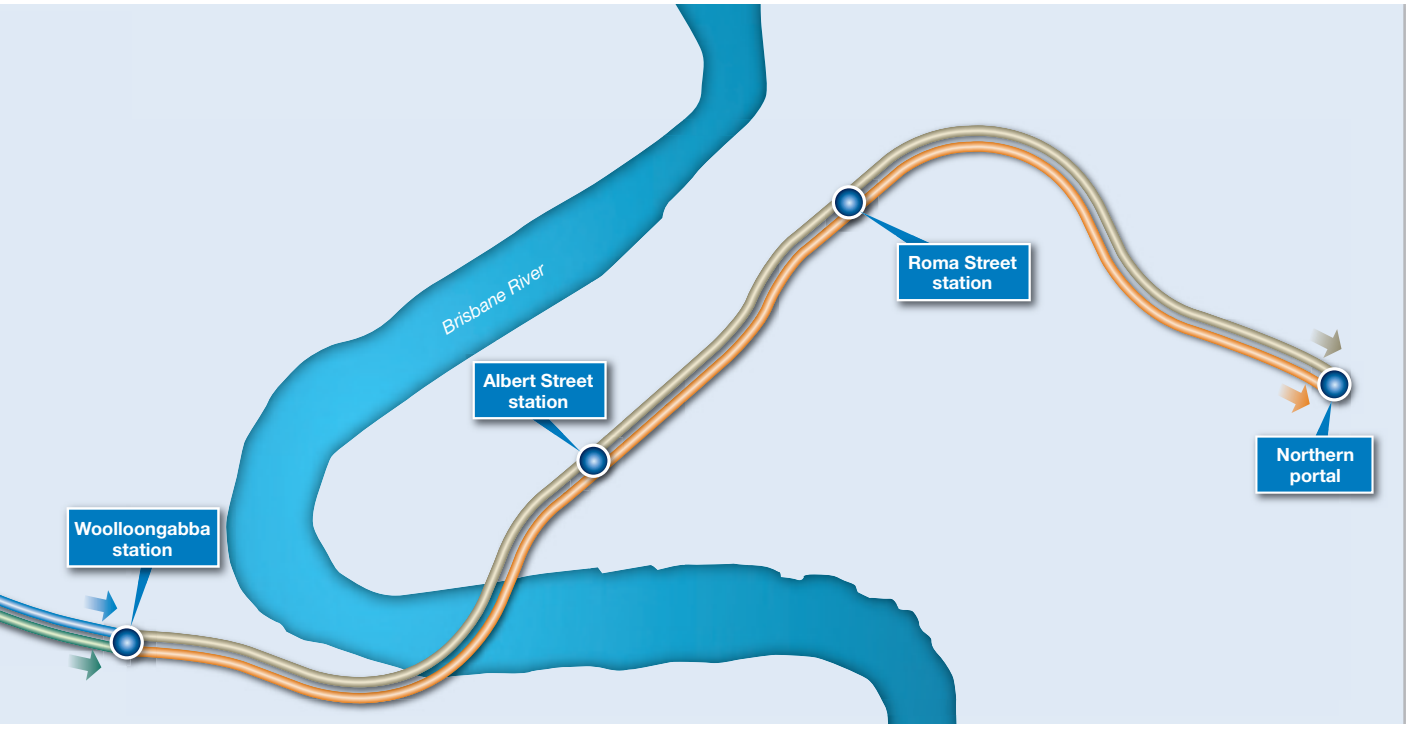
With the reference design determined, the environmental impact statement, including the required duration for public comment or objection, and business case are the next steps. The entire detailed feasibility phase has an expected completion date somewhere in mid-2011. At this point the governments will make an investment decision. If the project goes ahead, the tender process could be underway as early as the second half of 2011. The procurement phase should take approximately 18 months.

Project vision

Under the plan, a tunnel will run for 9.8km from a southern portal at Yeerongpilly Station to a northern portal by Victoria Park, passing under the Brisbane River. The Queensland Government has endorsed these locations and they form part of the Cross River Rail reference design, which was released by the minister for Transport on 11 November.

It will take the form of a twin-tube, single-track tunnel. This format has been chosen because it poses the least risk from any potential changes in geology along the route. The tubes will be separated by a central rock pillar,

Above, left: **Albert Street Station**
Above, right: **The Woolloongabba (Gabba) Station (both artist's impression)**
Below: **Plan of the proposed twin-bore tunnel with TBM drives**



which itself will be lanced at regular intervals by emergency evacuation passages. A permanent concrete lining connecting with the main tunnels will support the cross-passages.

The maximum grade of the tunnel will be 3 per cent, meeting rail tunnel specifications set by Queensland Rail. However, the majority of the tunnel will be less than this.

It is hoped that the rail tunnel will alleviate the stress on the existing network of an increasing population and increasing commuter workforce. The high capacity nature of the service should achieve this with little difficulty. Tunnelling as an option also results in minimal surface disruption to transportation, a necessity for this project that has increasing infrastructure efficiency as its sole objective.

The project is also intended to inject money into the economy and provide jobs during the economic downturn as part of a much larger Australian investment intended to offset the impact of global recession.

Tunnelling methods

Construction will primarily be undertaken by driven tunnelling, using two shield TBMs driving parallel from the southern portal to Woolloongabba Station in the middle of the alignment. A further two will run from Wolloongabba to the northern portal. Pre-cast concrete segmental linings will be used and the tunnel will be 6m internal diameter with a 7m bored diameter. When passing under the river, there will be approximately seven metres of rock cover to the water.

Where the sections are small and shallow, such as for cross passages, a roadheader or cut and cover will be used. 'Dive' structures connecting the tunnel to surface tracks will be excavated using open cut construction due. In areas with especially hard rock, it is foreseen that drill and blast may be necessary.

Underground stations are to be constructed using a combination of techniques, such as piled walls, rock cuttings, roadheaders and cut and cover. The south portal will be constructed with a reinforced concrete retaining wall with a soldier pile wall at the immediate portal and lattice arch girders to the floodgate shaft. The north portal will feature temporary soil-retaining walls near the surface as well as cast-in-situ walls.

The reference design incorporates the existing Queensland Rail 25-kV traction and overhead electrification system though new power requirements have resulted in the addition to the design of two new traction feeder stations at each end of the tunnel.

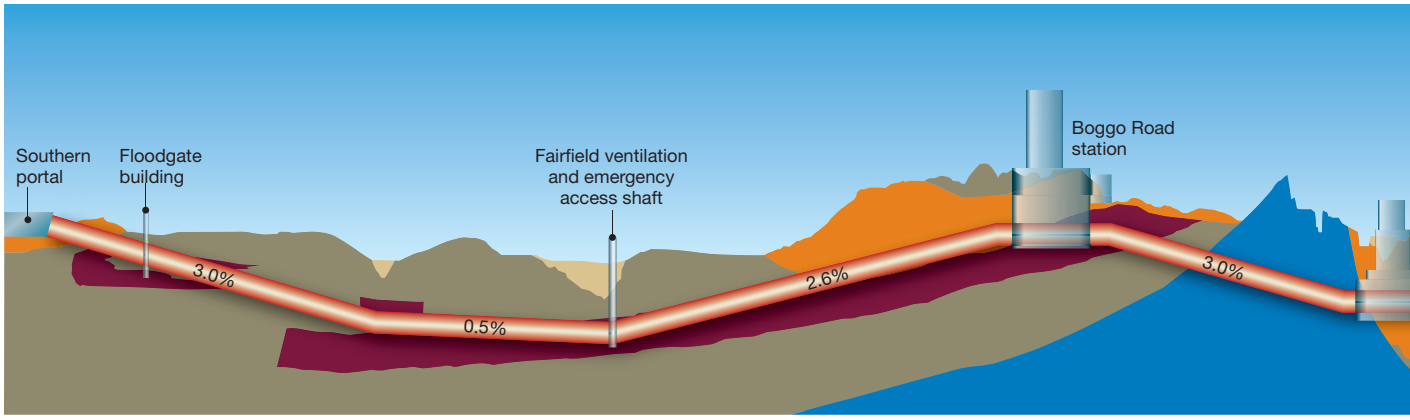
Ventilation systems will be installed at the entrance and exit of each underground station. The longest section of the tunnel (between the southern portal and Boggo Road Station) necessitates an additional shaft providing ventilation and emergency access.

Stations are to be of a length to accommodate trains of nine cars (220m) though the additional equipment at each end of the stations pushes this to 250m.

Geology

A series of bores and geotechnical investigations have been undertaken to ascertain the nature of the geology along the study corridor. These included a seismic survey in the river itself as well as drilling and testing the ground at the planned location of each station and at relevant points along the riverbank. Drilling and testing was also done south of Boggo Road Station for the running

Left: **Brisbane River at night**



Below: **Longitudinal geological section on the tunnel route**

Above: **South East Queensland**

tunnels. From this data and information from previous records, a 3-D geological model of the corridor has been constructed.

The tunnel has been designed to run along a course that allows the maximum length of the running tunnels to be through hard rock as it is the best way to minimise the effects of changing geology.

The proposed route is known to run through Neran-Fernvale Beds, Aspley Formation, mudstone, sandstone, Brisbane Tuff and alluvium.

One concern is the point at which the tunnel passes under the river, as the depth of the river crossing has been based on 'desk-top analysis' and seismic surveys.

Volumetric resumptions

A challenge in the reference design is that of present and future development requirements and stresses that will be placed on the tunnels and surrounding rock. The tunnel has been designed to cope with loads from existing buildings, proposed buildings and buildings that the land has potential to accommodate in the future. As an additional safety measure, volumetric resumptions of 7m on all sides (10m around the curve of the arch for station caverns) of the tunnel have been built into the design as an essential requirement. This distance of roughly one tunnel diameter ensures an adequate pillar of rock remains preserved against future development, in order to protect the integrity of the tunnel.

Alternatives to a tunnel

Cross River Rail has revealed that a number of other options had been considered to meet the objectives of the project during the Inner City Rail Capacity Study undertaken by the Queensland Government in 2008. These have included enhancements to heavy rail, expansion of the bus network, a light railway system, and a metro. None of the alternatives were deemed viable for the project.

Two statistics that Cross River Rail is particularly proud of are that, upon completion, the project will be able to move up to 120 000 commuters into the inner city from the north and south during the morning peak-travel and also that it would take a 30-lane motorway to provide the equivalent flow of passengers.

Constructing the periphery

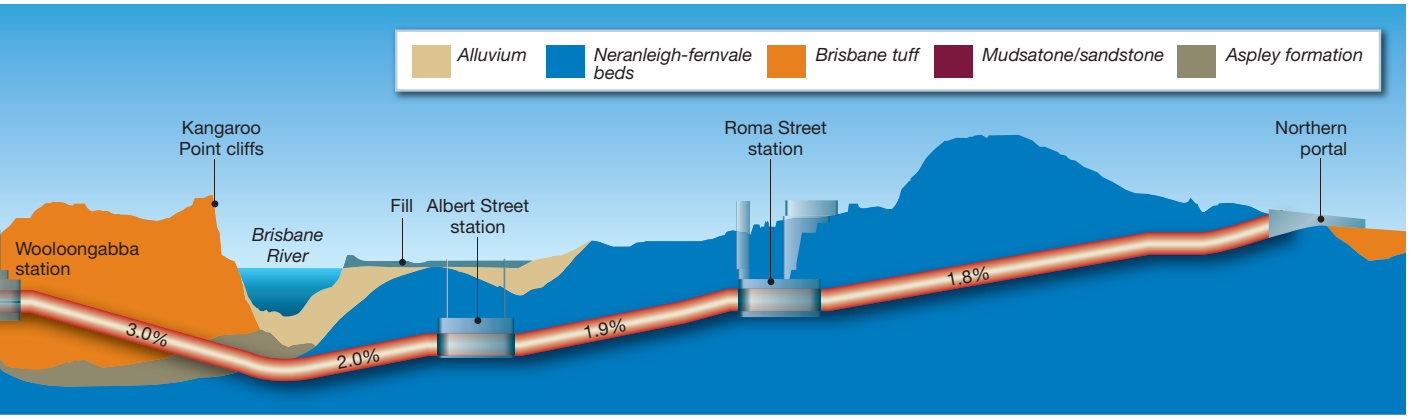
The Cross River Rail project is not 'just' a tunnel under a river. As well as underground construction works on the main tunnel, the project also requires substantial peripheral construction, worthy of several separate projects in their own right.

Of the road and bridge requirements, these works include the reconfiguring of the Sherwood Road to Fairfield Road southbound slip lane to accommodate a new rail-over-road bridge next to the existing bridge, the reconstruction of the southbound ramp on Ipswich Road to pass under a new span beneath the road, reconfiguring the Station Street link to accommodate the new line, the creation of a new overpass, realigning a street to better favour the new line, creation of a *cul de sac* at Norbury and Dollis Street on both sides of the Ravena Road overpass to accommodate the adjacent rail, a rail bridge over Muriel Avenue as well as one over Moolabin Creek and a road-over-rail bridge at O'Connell Terrace.

Rail structures required include traction feeder stations near the two portals at Yeerongpilly (southern) and Victoria Park (northern) as well as one near Mayne Yard, an elevated structure for grade separation and stabling connection, an elevated structure near Mayne Yard for connection to the North Coast Line and tracks for the 9.8km main Cross River Rail tunnel from Yeerongpilly to Victoria Park.

Other tunnel works include both portals and the respective 'dive' structures, a southern floodgate shaft to the north of Yeerongpilly and a ventilation shaft between Yeerongpilly and Boggo Road.

Also to be included is provision for a ventilation shaft near the north portal and provision for a possible future connection to a North West rail corridor.



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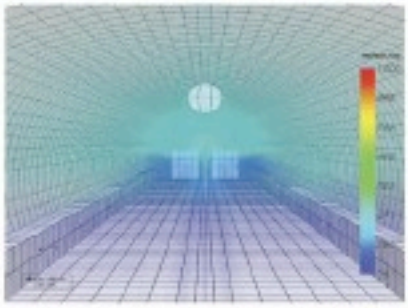
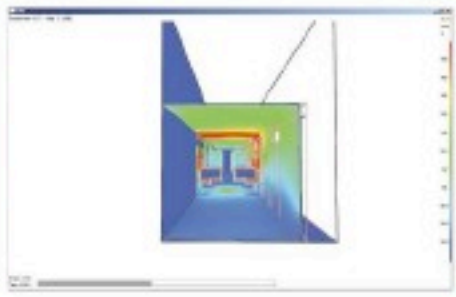


The theme of the Third International Tunnel Safety Forum (TSF11) is the future of tunnel design and operation, including assessment of the impact of major tunnel fires, accidents and terrorism in the last ten years. We are delighted to have key speakers who were closely associated with the incidents, both during the emergency and operational response phases.

Speakers and delegates will have the opportunity to reflect on the major incidents and lessons learned, and then consider new tunnels now in their planning stage and the next phase of tunneling projects; new technologies, operating procedures, designs and assessment methods.

This will be presented in a forum atmosphere that will encourage questions, debate and interaction between future project partners and key stake holders.



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Many technologies protect lives

Except for professional enthusiasts, the subject of worker health and safety is often considered boring. Indeed it has become a joke amongst the 'chattering classes' in reaction to over-careful authorities concerned about legal claims or hiked insurance premiums. And yet, in tunnelling it is a very real issue that should concern everyone.

The human factor, including both management and worker attitudes, is especially important in the working environment. Tunnelling can viewed as the meeting of the overly macho attitude of much of the construction industry (the 'it will never happen to me' approach) with the instinctive hazard awareness of the well-trained miner.

It was once, and often still is, the attitude of construction management that each worker is responsible for his or her safety and that of others. This is true of course, but it is not enough.

Some hazards should be obvious to any healthy aware worker – moving machinery, hanging rocks, and obstruction under foot for example. Adequate training should increase awareness of such everyday threats to safety. Other physical threats may not be obvious until an emergency arises, such as inadequate egress routes or ventilation in the event of a fire. In these circumstances it is the safe system of work that needs to be established by project management that plays the major role. Some additional hazards occurring only in an emergency may have note been recognised yet.

Can, for example, the smoke and fumes generated in the fire during tunnelling be adequately handled or prevented from harming workers? Fathi Tarada poses this question on pages 28-29. *T&TI* would be interested to hear your views too, especially about how such situations can be managed safely.

However aware a tunneller is, he cannot be held responsible for circumstances beyond his control. The design of safety into equipment, and making sure that safety keeps up with production technology, is vitally important. This is recognised in the establishment of frequently revised machinery standards such as the new CEN standards highlighted on pages 30-31.

Yet more hazards are virtually invisible and may only affect lives in the long term. So, all concerned should be made aware of them by training and warnings, including the precautions necessary to minimise or eliminate their effects, whether fatal or debilitating. Such hazards, often ignored, usually come under the heading of occupational health, and have often been reviewed in presentations by Donald Lamont (see pages 33-37).

Virtually any hazard found in tunnelling can be greatly reduced by the correct use of technology and design, from controlling working methods to providing the best working environment possible, and from guarding machinery to testing for gases and dust.

Safety and health are much more than watching where you go, providing personal protective equipment, and a conversational joke. Inadequate alertness to what could happen can damage, or remove, lives, long after one careless action.

Maurice Jones

Sentro 8 gas sensing

A fixed environmental gas sensing system, now being offered to the process industries, was originally developed and trialed in tunnelling.

The new system from Trolex, named Sentro 8, is an integrated multi-purpose sensing station ready to be configured to meet gas detection and condition monitoring requirements without the need for complex investment in system design or the need for specialist back-up, as has been the case with many fixed detection systems. The system has now also received ATEX approval (for explosive atmospheres) to widen its application.

Sentro 8 represents a simple and cost effective way to integrate sensors, controllers, alarms and other systems using compact stations. Each can simultaneously monitor the concentration of up to eight different gases or a combination of condition monitoring sensors; ambient temperature, ventilation, air velocity or any choice of remote connected sensors that is required.

The compact, high strength IP65, EMC-protected housing features a large LCD screen giving high brightness, dot matrix display for clear information about all eight sensor channels with direct on-screen instructions and diagnostic data. Also fitted are a powerful integral sounder and high intensity warning beacon. A large waterproof keypad provides direct access to the universal programmability and diagnostics of the sensor station.

The compact IP65 housing features a large, bright led screen to display information on eight sensor channels

The small overall size of the new development means that it is easier to design housings suitable for applications in hazardous areas and with improved levels of ingress protection, an important criteria in harsh environments. Intrinsic functional security is also considerably improved as the sensing system is engineered as an integrated whole. This eliminates the risk of invalid or unsafe equipment combinations that can occur in a piece-meal system.

Smoking tunnels

Dr Fathi Tarada, Managing Director of Mosen, raises the question 'Is smoke ventilation required for tunnels under construction?' in the light of recent dangerous incidents

Twin ducting arrangement for typical tunnel construction ventilation

In the wake of the Pike River colliery disaster in New Zealand, where 29 miners lost their lives, it may be time to reassess the issue of ventilation of tunnels under construction as well as mines. It is widely regarded that the Pike River disaster was caused by a methane build-up beyond the lower explosive limit of 4.4 per cent by volume. A total of four explosions resulted, with coal dust thrown up by the first explosion being involved in the subsequent explosions.

The fireball created by the initial explosion may have generated temperatures in excess of 1200°C, creating untenable conditions for human survival.

It is not just mines that are vulnerable to explosions and fires; tunnels under construction can also suffer from such events, causing great danger to human lives, and causing costly delays to construction programmes. A recent example is the diesel compressor fire in Canada's 10.4km long Niagara River Diversion Tunnel Project, which occurred on 27 April 2010.

Some 30 tunnellers working for contractor Strabag were forced to take refuge inside two emergency containers installed on the 14.4m-diameter Robbins Main Beam TBM, and four tunnellers were taken to hospital as a precautionary measure. The workers implemented the agreed emergency procedures, including attempting to extinguishing the fire. However, there was a large volume of smoke in the tunnel that needed to be dispersed.

Another recent fire in a tunnel under construction occurred in March 2010 at the 2.5km Vega del Ciego Tunnel that will form part of the high-speed rail line between Madrid and the Asturias region. The construction joint venture of Isolux-Corsan & Comsa (ICC) claimed that a spark in a sheet of waterproofing membrane caused the fire that then burned the tunnel's lining. The fire burned for nearly six hours, with more than 30 firefighters, mine rescue workers, ambulance workers and police involved in the control of the blaze. Five injured workers were treated for smoke inhalation and were all discharged the same day. Firefighters entered the tunnel from the southern portal and found the fire and heavy smoke about 500m from the portal. Fire chief Jaime Martin said that his men could hardly see through the smoke and that breathing apparatus was necessary at all times.

In the UK, a serious fire occurred in the Channel Tunnel Rail Link's (CTRL) Thames Tunnel on 16 August 2005. Two construction workers were killed in a fire that broke out in a diesel locomotive drawing a construction train south through the 2.5km-long, 8.15m-od eastern bore of the tunnel. Emergency services were called to the scene after a CTRL manager noticed smoke pouring out of the southern portal. Firefighters were able to extinguish the blaze with dry powder extinguishers before any major damage had been caused to the tunnel lining.

Fortunately the Saccardo ventilators for the permanent ventilation of the tunnel had already been installed, and this proved very useful in clearing the smoke from the tunnels. The fans at the Essex (north) portal of the bore where the locomotive was burning were actuated to blow the hot smoke away from the wagons containing large drums of cable, hence significantly reducing the potential fire spread. At the same time, the ventilators at both ends of the other tunnel bore were switched on. These pressurised the tunnel and cross passages to keep it clear of smoke. Tenable conditions for firefighters were therefore maintained throughout the fire incident.

Mechanical ventilation may be provided to tunnels under construction for a variety of reasons. It may be necessary to provide such ventilation to ensure an adequate air quality and temperature in the tunnels. Air quality is normally related to the dilution of pollutants (e.g. diesel smoke), the maintenance of adequate oxygen levels and the limitation of airborne dust (for visibility and breathability). Both air quality and temperature requirements for tunnel construction are reasonably well understood and catered for in the design of ventilation systems for tunnel construction. This understanding does not necessarily extend to emergency cases, however.

As evidenced by the incidents in the Niagara River Diversion Tunnel, Vega del Ciego Tunnel, CTRL Thames Tunnel and others, fires can generate a significant volume of smoke, even with relatively low heat release rates that do not threaten the structural integrity of the tunnel linings. Since most fatalities in fires are due to the inhalation of smoke rather than injuries due

to heat and flames, it is important to protect tunnel workers against the effects of smoke. In operational tunnels, smoke control may be achieved by moving the air in the desired direction at a velocity greater than the 'critical velocity' for smoke control. However, such a strategy may be too onerous in tunnels under construction, because of the large volumetric fan capacities that it would imply, and because the required air routes and power supplies may not be available yet. Alternative strategies such as the provision of pressurised emergency containers or the supply of breathing apparatus to tunnel workers are more realistic during the evacuation stage of a fire within a tunnel construction site.

Fire service personnel are often hampered by thick smoke during fire-fighting and search/rescue operations. The absence of a robust means of clearing smoke from a tunnel can therefore be a significant drawback, and can lose precious life-saving time. A number of fire brigades around the world have now equipped themselves with mobile ventilators to clear smoke from tunnels and underground spaces. For example, the fire service in Frankfurt am Main, Germany has both truck-mounted and track-propelled ventilators (with and without spray nozzles) that can be employed within the Frankfurt's expanding metro system. Tests undertaken indicate that the mobile ventilators can generate up to 3 metres per second within the metro tunnels, sufficient to clear smoke and allow a safe access to the seat of a fire.

BS 6164:2001 'Code of practice for safety in tunnelling in the construction industry' proposes that a safe system of work should be developed via risk assessment process, which includes consideration of the risk of fires. However, the issue of smoke ventilation is not explicitly considered. Although this standard is currently under review, smoke ventilation is not within the remit of the BS 6164 committee, and is therefore unlikely to be covered in the updated version.

Another issue that is relevant to fires in tunnels under construction is the types of combustibles that may be temporarily stored within the tunnel, or may form part of the tunnel structure. BS 6164 currently refers to the BS 476 series of standards for fire resistance, but makes no mention of the reaction-to-fire standards that specify limits to the heat release, production of toxic gases and flame propagation due to a fire (as provided by the BS EN 60695 series on 'Fire Hazard Testing', for example). Such specifications could conceivably have helped to mitigate the Vega del Ciego Tunnel fire that ripped through a tunnel waterproofing membrane.

The provision of emergency ventilation is clearly dependent on the fire risks perceived by a contractor, and will be contingent upon the type of construction method (e.g. TBM, drill-and-blast) and the phase of the project (e.g. boring works, electrical/mechanical fit-out, commissioning). Should any ventilators may be considered necessary, e.g. for smoke clearance, it may be agreed that these be deployed by the fire brigade rather than the tunnelling contractor.

Above: **A typical portable ventilation fan that could be used to remove smoke, but by tunnel workers or firefighters?**

Although the provision of emergency ventilation is not specified by the relevant tunnelling standards, the number of recent tunnel fires and explosions as well as their resulting casualties should give us reason to reconsider. After all, the provision of a safe system of work is clearly beneficial to all stakeholders within the tunnelling industry – and ventilation has a key role to play in ensuring a safe working environment for tunnel workers.

Right: **The 'Big Becky' Robbins TBM on the Niagara HEP project carries refuges that aided worker escape from fire smoke**
Below: **Inside a tunnel worker refuge chamber to escape from smoke**

CEN revised Standards for tunnelling machinery

Since the 'new' EU Machinery Directive 2006/42/EC came into force in 2009, all four standards dealing with tunnelling machinery had to be updated. Although these underwent simple amendment, published before the end of 2009, the responsible committee (CEN/TC151/WG4) considered it appropriate to undertake a full revision of the standards to address technological changes. This article is based on information from a paper on the subject presented to World Tunnelling Congress, Vancouver, May 2010

There are four CEN standards for tunnelling machinery safety covered by CEN/TC 151 'Construction equipment and building material machines – Safety'. These are:

- EN 815:1996+A2:2008 – Safety of unshielded tunnel boring machines and rodless shaft boring machines for rock – Safety requirement.
- EN 12110:2002+A1:2008 – Tunnelling machines – Air locks – Safety requirements.
- EN 12111:2002+A1:2009 – Tunnelling machines – Roadheaders, continuous miners and impact rippers – Safety requirements.
- EN 12336:2005+A1:2008 – Tunnelling machines – Shield machines, thrust boring machines, auger boring machines, lining erection equipment – Safety requirements.

Acknowledgements

T&TI **is grateful to Donald Lamont, formerly HM Principal Specialist Inspector and Head of Tunnel and Ground Engineering in the UK's Health & Safety Executive and now director of Hyperbaric & Tunnel Safety for permission to use information from the WTC paper on CEN Standards for tunnelling machinery. Other authors of the paper, all of whom also serve on the Standards Committee CEN/TC151/WG4, are:**

Werner Burger, manager of Design Division Traffic Tunnelling, Herrenknecht AG, Schwanau, Germany; K D Hagenah, Germanischer Lloyd, Hamburg, Germany and R Kampmeier, VDMA, Frankfurt, Germany.

These authors of the original paper would like to acknowledge the contribution to the drafting of the revised standards over many years by their colleagues on Working Group WG4.

All four were updated to reflect the essential safety requirements of the new Machinery Directive, with amendments published at the end of 2009. The further revisioning work undertaken by CEN/TC151/WG4 to address technological changes started on 8 October 2008 at the start of the 36 months required for standard development. Although standards EN 12110 and EN 12111 were revised according to normal procedure, the committee decided that there was now sufficient similarities between unshielded and shielded TBM design that standards EN 815 and EN 12336 should be combined, as well as revised, to form a single standard titled 'Tunnelling machinery – Safety requirements'.

All the revised standards were intended for CEN enquiry in 2010 and, if they received positive votes by the European members of CEN, will be published in 2012.

Combined tunnelling machinery

It became obvious that, in the light of practical experience, plus the development of dual-mode or hybrid TBMs, that there was no advantage is continuing with two standards for hard-rock and soft-ground machines. Basic design points regarding safety are similar for both. The new standard is also intended to cover future technological developments, and, of the types of machine covered, also includes microtunnelling, reaming and shaft-boring machines. A microtunnelling machine is defined, not by size, but by whether it is remote-controlled allowing man-entry only for maintenance when not operating. All other machines allow man access.

The highest priority in this revision is safe working when accessing the cutterhead for maintenance, since no 'maintenance-free' solution is yet available. Where possible, including all cutterheads above 4.5m diameter, cutter replacement must be carried out from behind the cutterhead (e.g., using back loader cutters). Where this is not possible, interlocked doors or guards have to be provided to prevent cutterhead movement from the normal controls. A local control station also has to be established.

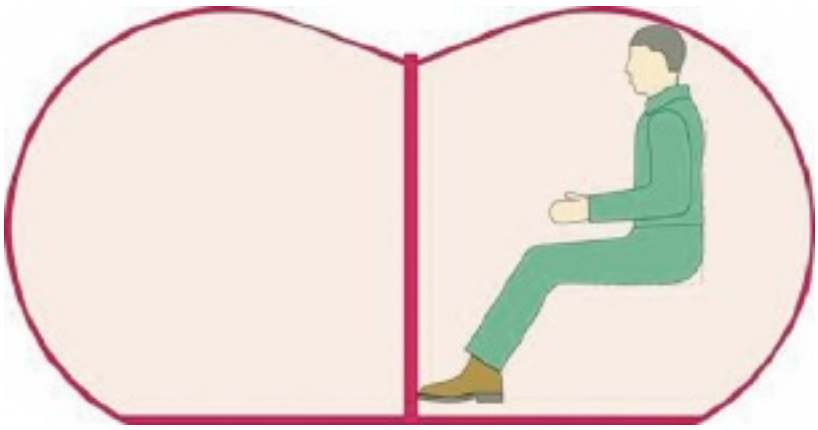
Segmental lining erection is also considered in the standard, especially in that the most productive work is still basically manual, despite attempt at automation. The common use of vacuum-assisted erectors has resulted in clear requirements for basic safety factors (SFs), with a minimum SF of 1.5 against pull off or sliding. If devices such as shear pins are not used, the minimum SF shall be 2.5.

The committee says one of the most difficult subjects for agreement in drawing up the new standard was defining minimum requirements for walkways and access openings in a basically confined space working environment. It was agreed that the geometrical limits for access on larger machines should be less restrictive whereas the old standards specified absolute minimum dimensions. The latter have been retained for smaller TBMs, based on the planned diameter inside tunnel support.

The minimum dimensions of walkways effectively determine the minimum dimensions for man access. There must also be consideration of the dimensions for emergency requirements such as stretcher carrying and breathing apparatus by rescue personnel, including maximum distances to 'safe areas'.

Airlocks – EN 12110

The revision of the safety requirements of this standard had to take into consideration many factors such as human



Left: **Non-circular TBM air-lock with 1.5m headroom for a 'large operator' [Picture: Herrenknecht]**

considerations, economics and feasibility. The scope of the standard only covers air locks attached to tunnelling machines and bulkheads for use in tunnels under pressure. More details of these and other hyperbaric equipment will be covered in another feature in *T&TI* later this year.

The German Federal Ministry of Economics and Labour strongly favoured a revision to address non-conformity with EU directives and to include state-of-the-art requirements. The committee's drafting group consulted with experts in compressed air work and in requirements for pressure vessels for human occupancy (PVHOs), as well as medical experts.

There is no limit specified in the standard on pressure, hence depth, but it is applicable to 5-bar, or 50m water depth.

It was decided that vibration, noise and electromagnetic compatibility associated with airlocks were non-significant hazards, but the list of significant hazards has been updated.

The design features of pressure vessels and parts has now been harmonised with the European Pressure Equipment Directive 97/23/EC.

For fire protection, fire-fighting and emergency provisions at the equipment control stand are now mandatory. The committee says that requirements for electrical equipment including emergency power supply and lighting are now better structured, with higher levels of light intensity. Also there must be an emergency pressure controller inside the chamber.

Table 1

Minimum walkway and access opening dimensions for different internal diameter of tunnel

Other matters considered in the revised TBM standard are:

- Design to avoid fire risk.
- Provision of fire detection system.
- Fire extinguishing systems.
- Explosion-proof gas detection for oxygen deficiency and flammable gases.
- Refuges based on project risk analysis. but with minimum requirements.

Other provisions covered in the revised Standard include:

- More ergonomic chamber dimensions and seating for 'large operators' during decompression.
- Larger windows for surveillance.
- Only water heating systems allowed,
- Noise levels (80 db(A)) harmonised with the Machinery Directive.
- Air quality.
- Oxygen breathing system safety.
- Slight changes to provisions for materials and combined air-locks.

Other tunnelling machines – EN 12111

The standard covers roadheaders, continuous miners and impact rippers, the latter consisting of a hydraulic hammer mounted on a crawler chassis. Before this work, the last amendment was to meet the requirements of Directive 2006/42/EC.

Much depends on the application of such machines and the committees CEN/TCs 151 and 196 had agreed this standard only deals with machines used in non-gassy environments. Those needing explosion protection systems are dealt with by CEN/TC196, chiefly, but not exclusively, for mining applications.

The independent CN machinery consultant was highly critical of aspects of the draft amendment to the standard and required a full revision as quickly as possible. The text of the revised standard has now gone to CEN enquiry.

There are said to be no radical changes proposed for the revised standard, but there are a number of detailed changes.

The current standard actually excludes requirements for the hammer used in 'impact rippers' and there is no positive inclusion of the crawler carrier either. Therefore 'impact rippers' have been removed from the standard and replaced with (detachable) cutterheads and impact hammers as found on versatile carriers such as hydraulic excavators. Roadheaders and continuous miners remain covered.

The tandard now requires the machine manufacturer to provide a main switch box, for electric drive machines, on the trailing cable between the machine and the tunnel supply. The location defines division of responsibility between the supplier of electrical power and the machine manufacturer.

There are also more rigorous requirements for access to parts of the machine to allow safe operation and maintenance. As regards the latter, it is now a design principle that maintenance should be able to be carried out at ground level.

Dust is well known as a possible hazard with such open cutting machines, especially silica inhalation. Requirements have been established for machines and attachments to reduce dust production and to improve dust suppression. Other revised provisions of the standard include:

- Better lighting of machine and surrounds,
- With heavier machines of low centre-of-gravity, stability is no longer an issue.
- Remote operation, automatic profiling and guidance provisions included according to the state of the art.
- Fixed fire extinguishers.
- Fuel and other fluid storage harmonised with other crawler machinery (in construction).
- Provision for towing, lifting and transport included according to Directive 2006/4/EC.

Next stages

The revised standards are now under CEN enquiry, due to be completed this spring. There may still be suggestions for changes or modifications at this stage before final publication, but the Working Group states that the basic content should remain.

Member countries then vote on the drafts (usually abstaining if not interested in the topic) and submit comments to CEN.

In parallel the independent CEN machinery consultant assesses the draft and makes comments. All comments are then resolved by the CEN Working Group and the document goes for formal vote. If positive it is translated into the official languages and becomes a harmonised standard after publication in the Official Journal of the European Union. If all goes well, revisions will be published in 2012.

The Working Group feels the target to include and reflect the latest development in what is still a fast developing technology for mechanised tunnelling (including the use of compressed air) has been achieved. Wherever possible, foreseeable future development has been considered as well. As has already been the case with the present CEN tunnelling standards, the Working Group feels that the revised version may very well be considered as a guideline far outside the CEN area.

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Overlooked hazards to occupational health

During safety campaigns, whether during planning or in-house inspection, often disproportionate attention is paid to more obvious physical hazards, overlooking those hazards that are less obvious but which call still lead to a deterioration in quality of life, and perhaps death, which can be difficult to relate to the working conditions. Drawing heavily on material supplied by Dr. Donald Lamont, formerly of the UK Health and Safety Executive, Maurice Jones examines the issues involved in tunnelling occupation health, and some other safety hazards, followed by some solutions

It is now widely recognised that occupational health and welfare does not tend to receive the attention that is afforded to lack of safety due to more obvious, and usually instant acting, physical hazards. Incidents such as tripping over obstacles, falling objects, bumps and collisions can result in many lost man-shifts, but at least their occurrence can be recorded fairly accurately.

Lost man-shifts, or deterioration in quality of life, due to insidious health hazards are much more difficult to record accurately. Nevertheless, Kevin Minton of the UK Construction Plant Hire Association has stated that a construction worker is 100 times more likely to die of work-related ill health than from an accident.

Dr. Donald Lamont reports that there is a general low-level of concern over occupational health in construction, aggravated by a previous lack of 'safety culture' in the industry and a macho image/attitude to working practices. He says, "HSE had little useful data on the numbers affected by ill health. Also the 'healthy worker' effect and transient nature of tunnelling make data collection even more difficult making it 'out of sight out of mind'!"

Since we are talking about underground construction, the intensive training on safety issues of most miners instils an instinctive awareness of physical hazards and some less visible but more familiar hazards such as methane gas. Yet even there an overly macho attitude or too much familiarity with some equipment can undo all the good work of training. Such circumstances include not wearing safety gloves when handling possibly hazardous materials, or riding on belt conveyors not designed for it.

Above: **Full personal protective equipment including a respiratory helmet is necessary in dealing with contaminated ground, as here at West Ham, east London [Photo: Costain]**

Lamont states that one cause of the problem is a 'lack of ownership' of the problem by some clients, designers and contractors. He also lists the transient workforce in tunnelling, and the nature of the work and working environment as contributory causes.

It appears that while attention to more obvious, and better-known health hazards has substantially improved, overall care for occupational health has not. In such circumstances hazards are either ignored (and it is easy to ignore some of these in the relatively short term of a tunnelling project) or they are left to another party.

"Occupational health is always the poor relation to 'safety,'" says Lamont. "Partly it is because of the long period over which problems normally develop and people move on or out of the industry. Partly there is a culture of hiding symptoms for macho reasons."

"Where countries have poor safety standards they most likely will have

very poor occupational health standards. Noise, vibration, manual handling, dust are universal tunnelling hazards. Heat is a problem in deep Alpine tunnels and hot climates."

There are two aspects of occupational health according to Lamont:

- To ensure fitness for work.
- To address ill health due to work.

Added to this is the need for a plan of welfare to ensure continued good health at work.

Fitness for work

Tunnelling is a physically demanding activity undertaken in and environments that are often hot and humid in a confined space remote from the surface. In addition, many projects can involve working in shifts and/or over long periods. Shift work can affect one's 'body clock' in upsetting sleep and eating patterns. Long hours are physically, as well as, mentally tiring, but in Europe are covered by the Working Time Regulations.

Lamont says that good practice suggests that all those working underground should undergo basic occupational health surveillance. This should indicate both the level of fitness at the start of a work period, and check for any deterioration after working. There also needs to be recognition that some safety critical occupations require a higher level of fitness. These might include working at height installing tunnel supports, or in particularly confined spaces such as in TBM forward chambers or air-locks, perhaps under compressed air atmosphere.

Plant operation, particularly transport work, may require particular abilities as regards fitness including good hearing and lack of colour blindness.

Eligibility for a rescue team is particularly demanding due to physical demands in environments that can easily be more extreme due to high levels of heat, wearing breathing apparatus, etc.

Before a tunneller is employed he or she should undergo screening to assess basic medical fitness for work, covering height, weight, blood pressure, function of heart and lungs, sight, hearing, level of diabetes, and health affecting practices such as smoking, level of alcohol consumption and drug use. The latter may be legitimately health-related, or socio-politically motivated drug abuse, says Lamont. In either case it can affect fitness for work, both physical and mental, for which the time and level of drug retention in the body should be considered

Above: **Tunnellers should undergo a health check before beginning work**

In addition the screening should be able to identify pre-existing conditions of occupational ill health such as noise-induced hearing loss and hand-arm vibration syndrome (HAVS) from excessive use of power tools, etc. The date collected will not only assess a candidate's suitability for work, but provide a base level to assess any subsequent deterioration, as can be determined by periodic reassessment.

Going back to compressed air work, the occupation is unusual in being covered by particular health requirements under statute. Only those medically fit can enter a compressed air environment as assessed by the 'appointed doctor'. Under European regulations checks include periodic MRI or X-ray scans along bones to check for bone necrosis. The frequency of periodic checks depends on the pressure to which the tunneller is exposed: every 28 days for exposure above one bar, and every three months for exposure below one bar. Compressed air and other hyperbaric work in tunnelling will be covered in another editorial feature in T&TI later this year.

Any work is association with asbestos is another particular circumstance covered by law. Under the UK Control of Asbestos Regulations, and worker exposed to asbestos must have had a medical examination in the two years prior to employment.

Ill health due to work

The potential hazards to health on tunnelling projects are many and widespread, but each can have its own combination including, perhaps, some special cases for concern. To put the known potential hazards to health in a list, which may not be comprehensive:

Physical hazards to health

- Noise
- Vibration
- Manual handling
- Heat/cold extremes
- Pressure

Chemical hazards

These may already occur in the environment of the new or existing, or be used in construction materials, and include:

- Asbestos
- Lead
- Silica dust
- Cement dust
- Epoxy resins
- Certain chemical additives
- Certain solvents
- Ground contaminants

Atmospheric contaminants including the above, and radon gas as a radiological hazard.

Biological hazards

- Ground contaminants
- Contaminated water

While each deserves attention Lamont says, "my feeling for health priorities in tunnelling would be noise, vibration, manual handling, dust and the need for good welfare facilities, to concentrate on just a few. These health hazards occur in virtually all tunnels. I am not talking deaths, but ill health starting as loss of quality of life and leading eventually to inability to work and the socio/economic consequences of unemployment."

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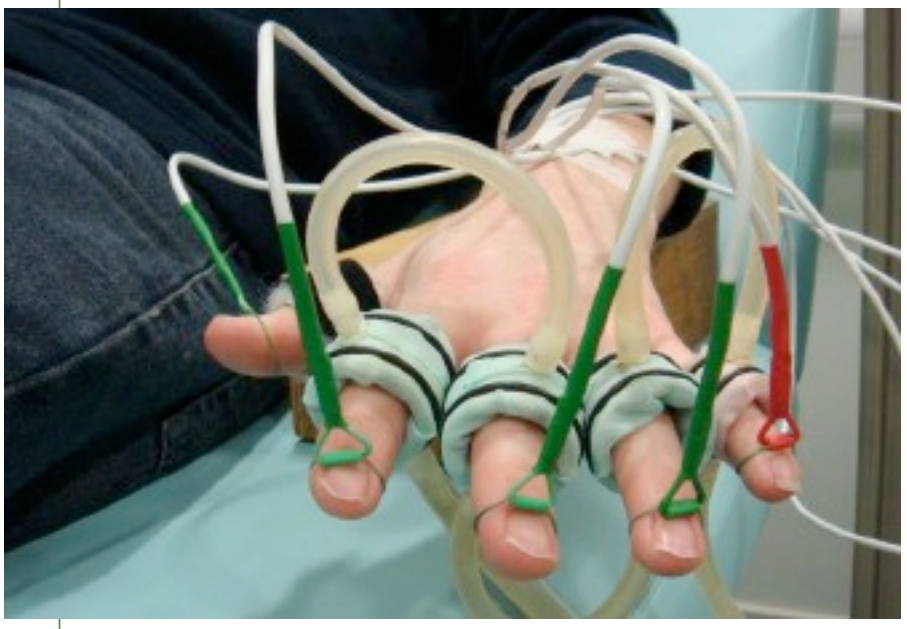

Left: **HVLab Diagnostic Equipment helps diagnose the vascular and neurological effects of hand-arm vibration syndrome**

Guidance

To learn more about potential health hazards, there is a substantial amount of guidance published by leading safety authorities around the world.

In the UK, the Health & Safety Executive (HSE) offers publications and advice via its website – http://www.hse.gov.uk/. There is a relevant British Standard, BS 614, and the British Tunnelling Society has produced publications on Hand-Arm Vibration Syndrome (HAVS), and the hazards and behaviour of Nitrous Oxide (NO) in tunnels exhaust emissions.

To learn more about the nature of health hazards HSE has conducted a number of research programmes. The subjects tackled include:

- Heat strain in compressed air tunnelling,
- Behaviour of nitrogen monoxide (NO – nitric oxide) in tunnel atmospheres,
- Behaviour of RPE (respiratory protective equipment) under pressure,
- Behaviour of atmospheric monitoring equipment under pressure,
- Monitoring decompression regimes in real time.

Prevention

In his presentation, Lamont sets out a list of the principles of preventing the effects of health hazards, in a recommended sequence of attention according to effectiveness if feasible. This is (with examples):

- Avoid the hazard (preventing interaction, physical removal, etc.)
- Combat risk at source (eg dust suppression)
- Adapt work to the individual (design task safety for worker's ability)
- Adapt to technical progress (see comments on newly revised CEN safety standards for mechanised tunnelling p30-31)
- Substitute by less/non-dangerous means (e.g., replacement of alkaline shotcrete accelerators by non-alkaline types)
- Collective protection over individual protection such as PPE (Personal Protective Equipment) (more effective and less prone to error PPE is NOT first choice)
- Instruction, training and supervision (in otherwise dealing with the hazard)

Leading health hazards

Considered below are the leading, but obviously not the only, hazards to health in tunnelling, as recommend by Lamont:

- Noise
- Vibration
- Manual handling
- Dust
- The need for good welfare facilities

Noise

Major sources of noise in tunnelling are drilling equipment, cutterheads, pneumatic and hydraulic power tools, fans and to a lesser extent transport systems. In the UK sources are controlled under legislation by the Machinery Regulations and the Control of Noise at Work Regulations 2005.

Despite any machismo/bravado exhibited by workers, the consequences of excessive exposure to noise can be severe. There can be hearing impairment with consequent diminished quality of life and possible incapacity for work (see above) even though physical disability is not obvious, Lamont points out. Consequently the extent of the problem is not recognised by society. It is understood that 50 per cent of miners have significant hearing impairment.

Prevention being much better than 'cure', the measures to be taken, mostly set out in UK legislation, include:

- Set out exposure action and limit values for noise exposure and for peak sound pressure.
- Require risk assessment.
- Elimination or reduction of exposure to noise, including noise enclosures if possible, plus good machinery maintenance, as far as in reasonably practical (SFAIRP).
- Measures (excluding provision of PPE) to be taken at the upper exposure action values.
- Provision of personal hearing protectors. Designation of Hearing Protection Zones. Health surveillance including audiometry. Information, instruction and training.

HAVS and HAV nots

The consequences of excessive vibration from power tools (basically HAVS) have received considerable attention in recent years both in UK tunnelling and elsewhere. This has led to measures such as improved designs of hand-held power tools, greatly limiting the working time when using vibrating tools, and, if possible, replacement with other methods of excavation, etc., including mini-excavators and purely manual tools.

A related hazard is whole body vibration (WBV) caused by ride-on operation of vibrating machinery such as locomotives and hard rock cutting machinery. This may be alleviated by better machinery design to isolate the seat from the rest of the machine by shock absorbers and cushioning.

The relevant UK legislation is the Control of Vibration at Work Regulations 2005.

The consequences of excessive vibrations exposure with HAVS are loss of sensation in the hands with initial tingling and numbness, loss of strength in the hands, discoloration ('white finger' – tips of fingers go white and then red, with in on recovery), and eventual incapacity for work. With WBV there is also incapacity for work leading from consequent back pain, and internal organ damage.

Actions to be taken to cut down the hazard include setting exposure limit values

(ELV) and exposure action values (EAV) (on an 8-hour average in UK legislation). Various graphical and tabular aids are available to judge actual values against these limits over time.

In line with the principles for action on noise there should be a vibration risk assessment and ensure that exposure risk is eliminated at source (SFAIRP) such as by good tool maintenance, and anyway to maintain that the worker is not exposed to vibration above the ELV. Measures are to be taken, excluding the provision of PPE, at the upper exposure limit. There should also be health surveillance, information, instructions and training about vibration hazards.

Other measures to mitigate the hazard include job rotation, keeping hands warm, and possibly anti-vibration gloves, although Lamont says these are of doubtful value.

Manual handling

Although legislation and safety enforcement has led to the provision of materials handling devices to aid work and to try and prevent injury, basic manual handling seems inevitable in many tasks underground including manual excavation (shovelling, digging and rock handling, etc), erection of (small) segments (unless manipulators available), erection of steel arching, installation of TBM cutters, picks, etc. In many cases the hazard can be from stretching as well as weight, so as may be the case with erecting support mesh without adequate access equipment. This seems to be an area where machismo and perceived convenience are short-term factors in developing long-term problems. Relevant UK legislation is the Manual Handling Operations Regulations 1992.

The consequences of excessive, inappropriate manual handling include musculo-skeletal disorder (including 'back back'), work-related upper limb disorder, and incapacity for work with probable obvious disability.

Manual handling must be eliminated as far as is reasonably practical, with the mitigation of risk from unavoidable manual handling. Such operations must be assessed, and reassessed if necessary, for possible improvement in methods together with instruction and information n the correct means of lifting, pulling and pushing. Common advice on manual handling includes avoidance of repetitive work, avoid manual handling in confined spaces, and in hot/humid conditions, and avoid twisting and turning when handling

Mitigation measures that can be undertaken include:

- Make things too heavy to lift manually so that mechanical aids must be used.
- Mechanical excavation aids instead of hand tools.
- Use of segment hoists and erectors.
- Lifting points in cutterheads.
- Handling aids for cutters and picks.

Dust

One of the most insidious hazards underground is dust, particularly when airborne, with some dusts more dangerous than others depending on the interaction with the human body. Dust hazards are normally considered to be due to inhalation, but some fine or unusual chemical dusts can cause skin irritation and inflammation (dermatitis). Many today are still suffering the effects of excessive dust inhalation from when suppression was not considered, resulting in pneumoconiosis in general, or the more sever silicosis and asbestosis.

Sources of dust include rock cutting, lifting from the invert by ventilation of people/vehicle movement, concrete spraying and mixing materials.

Dust can be categorised into inhalable dust (maximum UK exposure – TWA limit of 10 mg per m3 over 8 hours), respirable dust into gas exchange regions of lungs (4 mg per m3 TWA) or the more serious respirable crystalline dust at 0.1 mg per m3 limit. Workplace Exposure Limits (WELs) have replaced the old OELs and MELS with values as 15-minute or 8-hour time weighted average in dust sampling.

Excessive exposure can lead to lung damage with severe respirator and consequent heart problems, with loss of quality of life, incapacity for work and early death.

Actions to be taken on dust control can start with monitoring through air sampling general or personal) and dust lamps to indicate its presence in the air. Dust caused by rock cutting should be suppressed at source by water sprays and or removed by extraction fans.

Roadheaders complying with the new EN 12111 standard are equipped to deal with dust in such ways. Dust from sprayed concrete can be minimised by using wet-process rather than dry-process equipment.

If dust cannot be eliminated at source, adequate ventilation is required to remove it, preferably by a forced and extraction dual duct system with dust filters and scrubbers in the ventilation stream. As a last resort, or additional precaution, specially designed dust masks can be used.

The health of those that might be affected by dust should be checked using a lung function spirometry test, and periodic X-ray or RMI scanning.

Welfare facilities

Provisions of facilities to improve the welfare of employees during and after work can produce benefits in hygiene, well-being, and employee satisfaction through respect and less stress, resulting in improved performance.

Facilities listed by Lamont that should, or must, be available include basic toilets, washing facilities, mess/eating areas and first aid provision.

Other considerations relate to the normal lifestyle of the workforce. As peripatetic groups they often lack basic access to national health service facilities. Lamont says consideration should be given to providing general practitioner services in remote locations, plus dentistry and chiropody services.

Internationally

Although this article is based mainly on UK experience, good practice around the world is similar. "Noise, vibration and manual handling are all covered by European directive so standards should in theory be similar throughout Europe," says Lamont. "The USA, Canada and Australia tend to be on a par with Europe. The Far East adopts UK practice where there is a history of UK involvement, such as in Singapore and Hong Kong. Elsewhere things may not be so good."

Conclusions

The occupational hazards to health dealt with in this article may only be a small part of those that could be encountered in any one tunnelling project. The risks arising from them can be mitigated in the design and construction of tunnelling projects, but preferably eliminated when found if possible.

Lamont says that, apart from (the use of) compressed air, none of the hazards discussed are unique to tunnelling, but what is unique is the complexity of the combinations in which they are found.

Acknowledgement

This article is based on information drawn from a presentation made by Dr Donald Lamont, director of Hyperbaric & Tunnel Safety Ltd, and formerly HM Principal Specialist Inspector and Head of Tunnel and Ground Engineering in UK Health & Safety Executive's Civil Engineering specialist team, to the Young Members Section of the British Tunnelling Society, for which *Tunnels & Tunnelling International* is grateful to Dr Lamont.

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Hard-rock TBM performance prediction

The authors (see separate block), present a paper covering an improved method of predicting penetrating, cutter wear and advance rate by calculation for TBMs in hard rock

Performance predictions form an essential basis for the calculation of costs and the operational planning of construction projects. In tunnelling, the main performance figure is the advance rate. Especially in long tunnels, a prediction of advance rate that is as accurate as possible is of great importance, even in early phases of the project. As realisation is coming closer, the exact planning of the construction operations becomes more and more important. This requires an even more exact prediction of advance rate.

For the contractors, advance rate is a crucial parameter for the calculation of their tenders and for assessing the scheduling risk. For conventional tunnelling, analysing the cycle time has become a proven method to calculate the advance rate. The results are normally within an acceptable bandwidth.

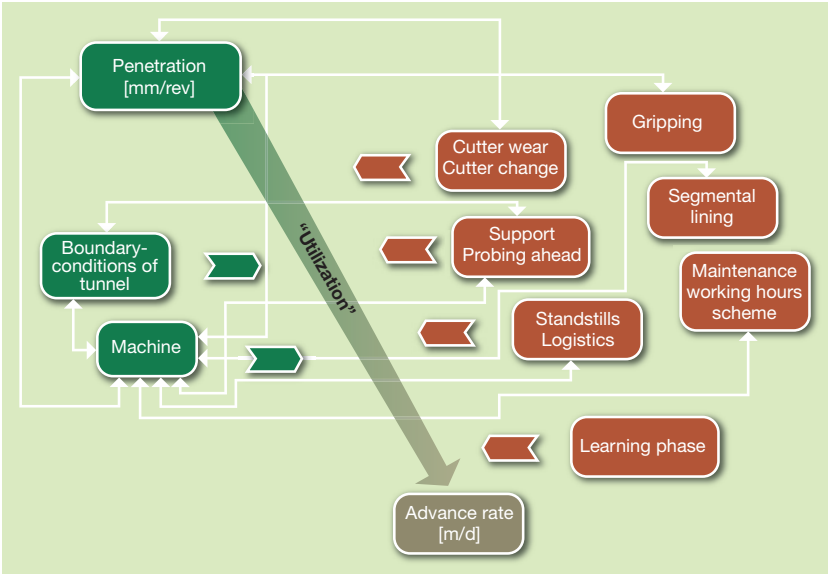
No standard method of calculation has so far established itself for mechanised tunnelling. As has been found in tenders, the advance rates predicted by tenderers are sometimes a long way from reality. This situation, which is criticised by L. Home[1] using the words 'Tolerance of inaccurate estimations is hurting our industry' [Ref 1], is extremely unsatisfactory for all participants of a project. The causes for this situation are investigated below, and a new method of calculation will be presented, which leads to better, i.e., more accurate, results.

Basis

In order to predict advance rates for TBMs in a given geology, the first thing that has to be calculated is the penetration rate, expressed in millimetres advance per revolution of the cutterhead. The next step is the calculation of the net boring speed, which depends on the cutterhead rotation speed, in metres per hour. The following step leads from net boring speed to the advance rate. In this step, the obstacles, malfunctions, and downtimes of boring operations must be taken into account. This happens in many cases by using a general utilisation factor (in percentage terms) or, if the calculation is more exact, by estimating the total downtime in minutes or hours per shift or working day.

Another factor that must be included into the calculation is the excavation time, i.e., the working time available for excavation. This is a maximum of 24 hours per day. If a regular maintenance shift is planned or if the working time model does not provide for 24-hour operation, the time for excavation is accordingly less. In rock formations with a high share of abrasive minerals, cutter wear has to be considered in the calculation. As soon as the time available in the maintenance shift is insufficient to do all necessary cutter changes, the time available for excavation is automatically reduced. The situation becomes even worse if individual cutters must be changed during the excavation time as a result of impact damage. With gripper TBMs, the amount and type of support to be installed immediately behind the cutterhead also have a major influence on advance rate. The installation of shotcrete in this area almost always leads to an interruption of the boring cycle, while anchors, steel mesh, and steel channels can normally be installed simultaneously with the boring progress. In addition, various aspects of machine design, construction operations, logistics, and organisation must be taken into

Below: **Figure 1 – Interdependencies from penetration to advance rate**



Authors

Univ Prof Dipl-Ing E Schneider, Department of Construction Management, University of Innsbruck

Dipl-Ing. Dr. echn. M Spiegl, Managing director of SSP BauConsult GmbH, Innsbruck

Dipl-In. M Turtscher, Department of Construction Management, University of Innsbruck

Dipl-Ing Dr techn. W Leitner, G Hinteregger & Sohne, BaugmbH, Salzburg

account in calculating the advance rate. The quantitative inclusion of all these parameters, interdependencies, and influences is all but simple and—since several iterations for the calculations are necessary—is only possible in a complex calculation model. Figure 1 shows the main interdependencies.

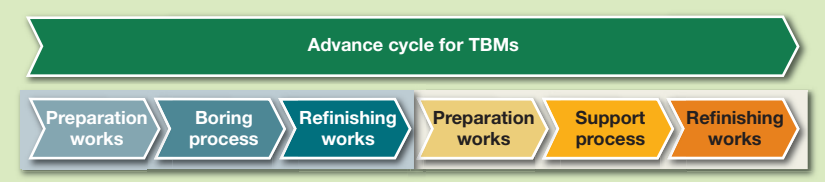
In practice most calculation models use simplified algorithms, which only take the major relations into account. Also, there are many projects in which not all necessary data for an accurate calculation of the advance rate is available. Experienced users, in particular the construction contractors working in mechanised tunneling, are often able to compensate these deficiencies by their own experience. In view of the essential influence of the advance rate on excavation prices, on time-dependent site overheads and the fact that advance rate must be guaranteed by contractors in many cases (or is at least penalised through deadlines) there is a high risk to take for contractors. Motivated by the analysis of a large number of tunnels excavated by TBM and by the wish to find a better solution to a problem that has so far been solved unsatisfactorily, the authors have developed a new model to calculate advance rate with a software that takes the complex interdependencies into account simplifying the complicated calculation work for the user.

State of the art

There are a number of models to predict the penetration rate. They are based on different concepts and on different experiences. The best-known models are the CSM[2] model (1993[3]), the model by Gehring[4] (1995) and the NTNU[5] model (1998). They are used individually, but sometimes also in combination with each other[6]. TheTBM manufacturers and some experts also use their own or modified standard methods for calculation.

Since the models have been developed mainly to predict penetration, none of them contains a method for calculating advance rate that meets the requirements outlined above. In most cases, they are limited to determining the penetration rate; several models also include methods to calculate cutter wear. However, various authors, among them N Barton [ref 3], have established a correlation between net boring speed and advance rate on the basis of empirical data.

A. Bruland, who in his thesis [ref 4] developed the current version of the NTNU model, has shown a way how advance rate can be derived from net boring speed by employing a general 'utilisation factor'. Another kind of information on the amount of utilisation rates can be found with M Alber [ref 5], who places utilisation rates in relation to the stability of the rock mass. The knowledge of contractors who are the real experts on utilisation rates is normally kept as a business secret and is rarely published.



Above: **Figure 2 – Advance cycle for single shield TBM**

Proposals for improvement

The current practice of modelling TBM advances as semi-continuous processes and to calculate advance speed on the basis of penetration rate, cutterhead speed and daily working hours in combination with utilisation rates, possibly detailed by specific calculations for gripper setting, ring installation and other downtimes, provides only an incomplete model of reality. In calculating advance rate, it is much more fitting to take into account that TBM advance is not a continuous process but always (i.e., regardless of the machine type) an intermittent (i.e., cyclical) one. This is made evident from Figure 2, which shows one stroke with a single shield TBM, where support is provided by segments.

The cyclical approach makes it possible to consider interruptions and downtimes directly, and according to the cause in calculating the duration of cycle times. Since the durations of individual working procedures can be entered in minutes, a detailed target/actual comparison of downtimes is possible during execution. This is much more meaningful than a target/actual comparison of total times or total utilization rates, which does not provide information on the reasons for different standstills. It was W. Leitner who first described and modelled in detail the processes of construction operations in mechanised tunnelling using this approach. In his dissertation [ref 6], he developed algorithms to this effect for all machine types used in hard rock (gripper TBM, single- and double-shield TBM). These algorithms formed the basis for programming the software presented below.

Penetration rate calculation

As shown in Figure 3, the penetration rate depends on three main factors: the machine, the rock, the rock mass and their interactions.

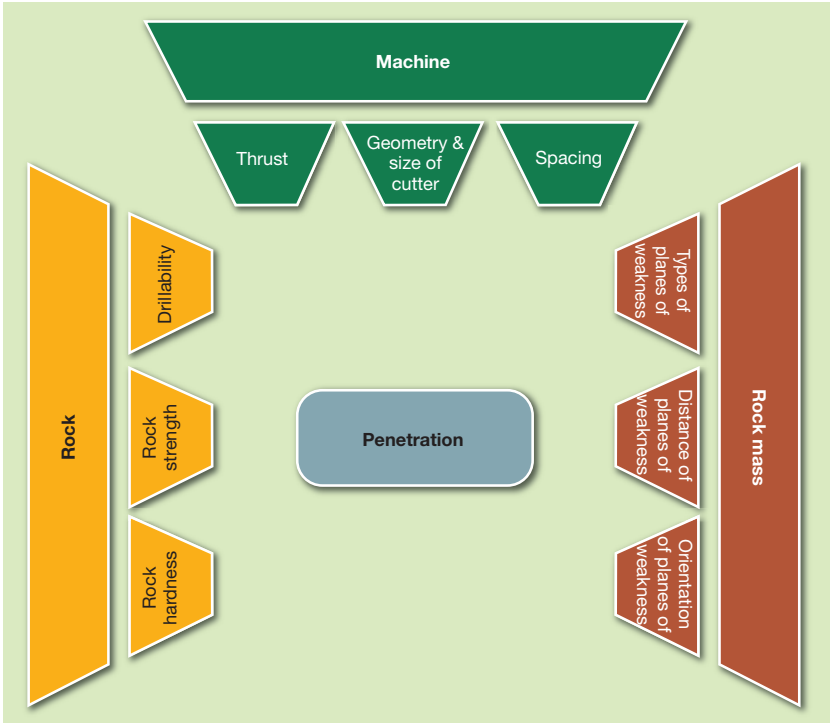
Standard models

Discussing the advantages and disadvantages of the different models for predicting penetration rate, let alone describing the models not explicitly mentioned, would be beyond the scope of this paper. What all models have in common is that they rely substantially on the evaluation of data of completed projects. Thus, the database used is of crucial importance.

In the CSM model, these are mainly data of TBM tunnels in Northern America; with Gehring, they are figures from publications together with data of TBM-bored tunnels in South Africa and South Korea. The NTNU model uses data from tunnels in Scandinavia and abroad. It was when the mechanised excavations in the Alptransit projects in Switzerland were started that a new chapter was opened in hard rock tunnelling by TBM. Therefore it was obvious to use data of these and other

Table 1: Members of the Abrock research group

Name	Institute	University
Prof E Schneider	Institute of Construction Management (co-ordinator)	UIBK University of Innsbruck
Prof K Thuro	Dept of Engineering Geology	TUM University of Technology, Munich
Prof R Galler	Institute for Subsurface Engineering	MU Leoben
Prof G Anagnostou	Institute for Geotechnical Engineering	ETH Zurich
Prof J Zhao	Laboratoire de Mechanique des Roches	EPF Lausanne



Above: **Figure 3 – Major parameters influencing penetration rate**

large traffic tunnels that have been excavated since 1990, or are going to be excavated in the next few years, to either improve an existing model or to develop a completely new model. A major factor for the decision to start this endeavour was the fact that most of the tunnels completed before 1990 had diameters < 7.0m, while modern road and railway tunnels normally require a diameter >9.0 m.

The further development of machine technology (diameter and material of discs, cutterhead geometry and cutter bearings, continuously adjustable rotation speed and the like) let some prediction models appear rather old. Essentially, the only model with continuous further development is the NTNU model, but even there the data forming the basis of the 1998 version is already older than 15 years.

New model development

In order to remedy this shortcoming, in 2006 the research project 'Abrock Analysis and Prediction of Penetration and Cutter Wear' was initiated by E. Schneider. Five renowned university institutes from the Alpine region have banded together to form a research group (see Table 1).

With the support of associated partners from the industry (clients, consulting engineers, contractors, and TBM experts) the teams of the involved institutes work in part projects, which ultimately shall be put together to create a new or improved prediction model.

Using laboratory tests with rock samples, which are mainly carried out at the University of Technology, Munich, and cutting tests using a linear cutting machine that is available to the University of Leoben, known correlations will be reviewed and new correlations—such as between penetration rate and destruction work—shall be investigated in detail. Fundamental research on fracturing under dynamic load shall be carried out using a new testing machine developed at EPF Lausanne. All test series shall be accompanied and supported by numerical modelling and simulations.

The influence of tension in the rock mass and the influence of cutterhead shape on the cutting process is investigated at ETH Zurich. At the University of Innsbruck, geological-geotechnical data and operating data of completed TBM tunnels are fed into the model of Gehring [ref 7]. It is then examined if the consistency between theoretical (calculated) and measured penetration rate can be improved by varying the approaches used in the model or by introducing additional influencing factors. The geological-geotechnical input values for the new model will mainly be found by internationally common and largely standardised physical testing procedures (UCS, BTS and destruction work). The only index test that the Abrock research group considers to be indispensable is the Cerchar abrasivity (CAI) test. In the opinion of the Abrock, other index tests, such as those necessary for the NTNU model, are not sufficiently common and are also not really representative for the cutting process performed by disc cutters[7].

Cutter wear

As already mentioned, the standard models to predict penetration rate also include modules to predict cutter wear. The algorithms contained in these models were deduced from regression analyses based on old data material. Therefore the demand for improvement in this field is also urgent. First findings, which will be published shortly [ref 8], has already been made by a member of the Abrock research group by evaluating recently excavated tunnels.

Advance rate calculation

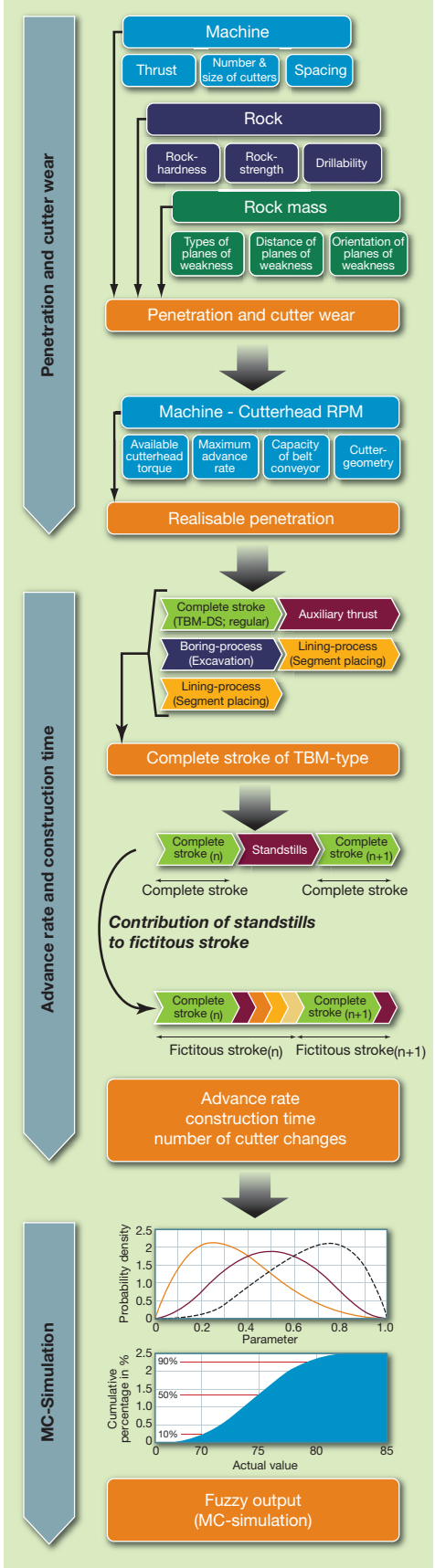
In this step in the calculation, which leads from penetration rate to advance rate, not only aspects of construction operations, organisation, and logistics should be considered, but also those parameters and conditions of machine design that have not been included into the calculation of penetration rate. Relevant parameters are:

- Cutter head rotation speed.
- Available cutterhead torque (depending on cutterhead speed).
- Maximum speed of extension for thrust cylinders.
- Maximum penetration depth of disks (depending on cutter geometry).
- Maximum cutter wear.
- Maximum thrust at cutterhead.
- Maximum thrust per cutter.
- Necessary minimum thrust per cutter.

In addition to the direct influence of the rock and the rock mass in calculating penetration rate, the indirect influence of the rock mass resulting from the installation of support measures must be considered in calculating advance rate. With gripper TBMs, it is the time demand for the support measures and, with shielded machines, the time for the installation of segmental lining that have a major influence on advance rate.

Another factor that can have major influence on the advance rate in abrasive rocks is cutter wear. If more cutters must be replaced than is possible in the time provided for this (i.e., the maintenance shift), the time available for boring is reduced. Unscheduled cutter changes also lead to a reduction in advance rate. Other parameters determining performance to be taken into account are:

- Capacity of the mucking system.
- Capacity of the logistics system.



Left: Figure 4 – Flow chart and functions of Simtunnel Pro 2.0

From the organisational sector:
- planned/available excavation time per working day.
- working days per month/year.
- loss of performance due to the learning phase.

This list, which is not claimed to be complete, may suffice to show that the calculation of advance rate by means of a simple spreadsheet is hardly sufficient. For this reason the first version of 'Simtunnel' using the algorithms of W. Leitner [ref 5], which was developed in 2005 by a student of the University of Innsbruck, was programmed in Java. The software was at the time distributed as freeware together with a (not free of charge) standard calculation for the costs of TBM advances, which was developed in cooperation with a renowned software house[8] at the same time.

Simtunnel Pro 2.0 new programming

Since the first version did not meet the wishes of users in all aspects and also did not take all basic conditions into account, the program was re-developed from scratch in 2009. This time, Simtunnel Pro 2.0 was programmed much more professionally in a programming language (Matlab) that was more appropriate to implement the necessary algorithms and interdependencies (see Figure 4).

The software includes the following new features[9]:
- Default settings for all values (can but need not be changed by user)
- Option to do the calculation with fuzzy input parameters (rock properties, operational parameters, etc.)
- Integration of a module to calculate penetration rate and cutter wear. Selection of Gehring, NTNU, or CSM model; also with individual modifiers[10].
- Works with any working time and shift model
- Takes the learning phase into account (modelling according to Wachter [ref 9])
- Central input table for all values (rock, rock mass, TBM, operation, etc.)
- Result displayed in the form of:
  a) a standardised report
  b) a construction time schedule in various graphics and vector formats
  c) an AutoCAD script file

The tunnel can be divided into any number of homogeneous or advance sections for calculation. These can be calculated individually, with the copy function of the program being especially useful here.

A further subdivision by excavation class, which might be possible in tunnelling with gripper TBMs, is optional. Parameters are entered and calculations are made by sections.

Results are displayed by section and in total; mean values are generated and displayed automatically. With deterministic calculation, discrete values are shown for advance rate, advance time, and number of cutter changes. With probabilistic calculation, distribution functions for advance rate advance time, number of cutter changes, etc., are shown together with mode, fractals, etc.

A standardised technical report in MS Word is output as the calculation result, together with a construction time schedule as an image file or in vector format (distance-time diagram) as well as pie charts for the various activities. Display is from portal A to portal B in total, broken down by advance sections or homogeneous areas.

Summary

There are proven models for calculating penetration rate. Since the underlying data is relatively old and mostly from tunnels with diameters <6.0-7.0 m, this material is no longer up to date. Also, there has been considerable progress since 1990 in TBM technology, in particular as far as cutters are concerned (material, shape, and diameter of disks).

The changed situation has motivated a research group consisting of five university institutes from the Alpine region to pick up the topic of the prediction of penetration rate and cutter wear, with the objective of developing a completely new or improved prediction model. However, penetration rate is only one—although the first and major—parameter to calculate advance rate.

The prediction of advance rate is essentially a task of construction planning, in which aspects of machine technology, operation, organisation and logistics must be taken into account. A simple straightforward calculation is insufficient for doing this: calculation must happen in iterative steps.

On the basis of a doctoral thesis accepted in 2004 at the University of Innsbruck, an engineering firm specialising in construction planning and economics[11] has developed the software Simtunnel Pro 2.0 making it possible to calculate advance rate in a comprehensible way, taking all conceivable influences and basic conditions into account.

A more accurate method of hard-rock TBM performance prediction is required, as suggested by the paper, for better project estimation. [Photo: The Robbins Company]

Endnotes

1 President of The Robbins Company, USA
2 Colorado School of Mines
3 Listed by year of last publication
4 Former Head of F&E, Voest-Alpine Montantechnik, Zeltweg, Austria
5 Norges teknisk-naturvitenskapelige universitet I Trondheim, Norway
6 eg E Buchi, who takes the CSM model as a basis and combines it with parts of the NTNU model in order to take ointo account rock anisotropy and fracture joints (see refs. 2 and 4).
7 However, this does not reduce the popularity of the Norwegian model. One of the reasons may be the fact that the diagrams in the publications of the NTNU permit an estimation of the values DRI and CLI , which are necessary to calculate penetration rate, without having to carry out the corresponding tests
8 AUER – Die Bausoftware GmbH; www.bausoftware.at
9 www.simtunnel.com
10 In addition, it is of course also possible to enter penetration and wear data directly, which have either been estimated, given by TBM manufacturers, or calculated by external experts.
11 SSP BauConsult GmbH, Innsbruck, www.sspbauconsult.at Literature/References

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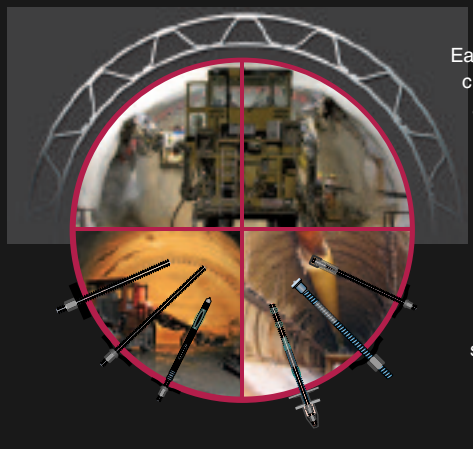
GROUND CONTROL SOLUTIONS



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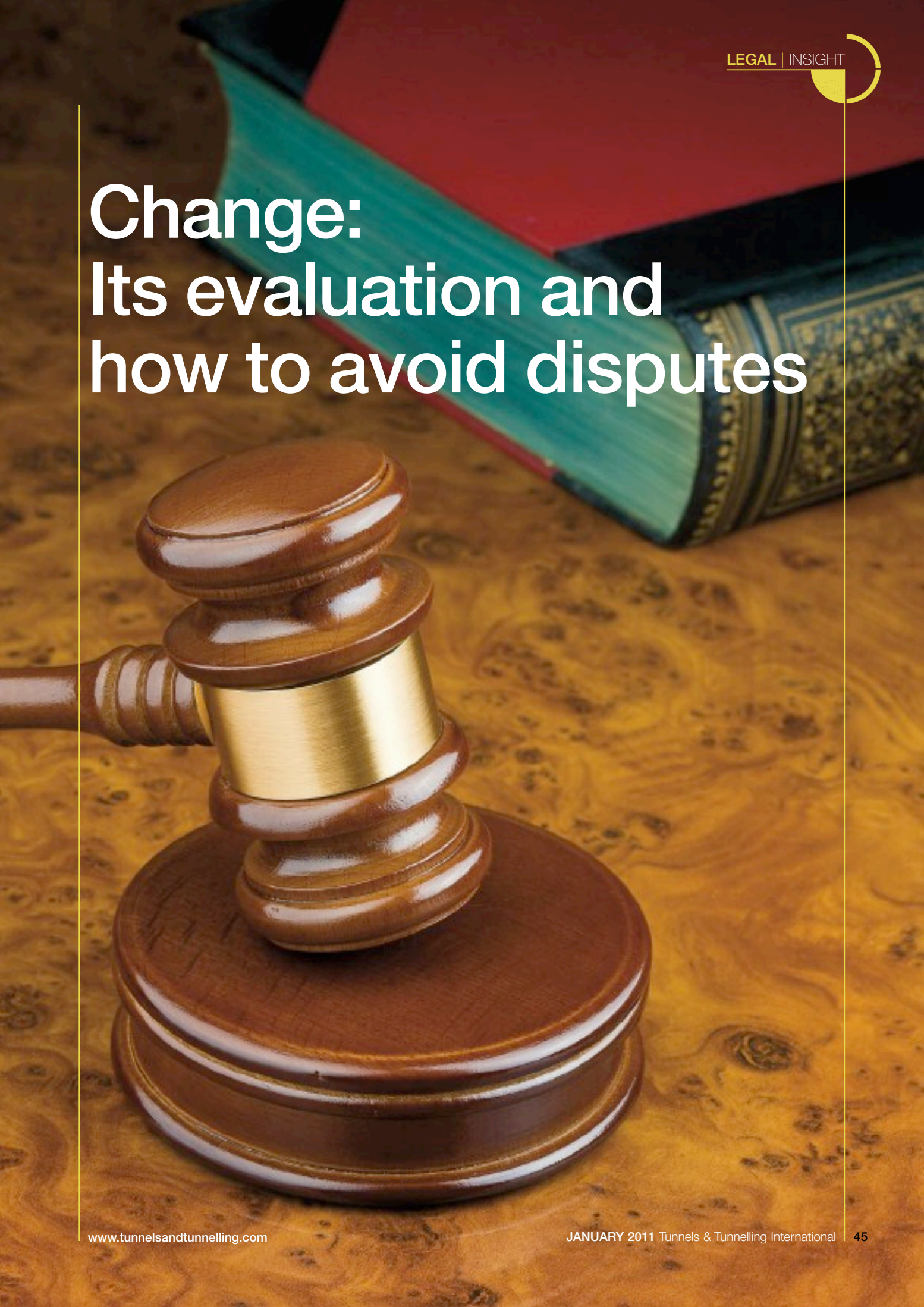
Change: Its evaluation and how to avoid disputes



Following on from last month's Change: Project & Legal Perspectives, P Greenwell and M Mills of Navigant Consulting consider the evaluation of programme and quantum aspects of change in respect of live tunnelling projects. The authors identify common pitfalls which can so often mean that 'change' and 'dispute' have become almost interchangeable

There are a number of frequently discussed methods of investigating the impact of change on a project when considered after the event. While these methodologies can be fascinating, they do not normally represent the main focus for the project team during works. We will therefore try to concentrate on the evaluation of change whilst the project is in progress.

What the contract says

The first article in this series (p42 T&TI, December 2010) sets out the common forms of contract to be expected on tunnelling projects: the International Confederation of Consulting Engineers contract (FIDIC) and the third New Engineering Contract (NEC3).

These are very different in their approach to the use of the programme in evaluation and entitlement of change. The change in mind-set required to move from an Institution of Civil Engineers (ICE)/Joint Contracts Tribunal (JCT) contract to an NEC-governed project is considerable.

The other commonly encountered tunnelling contract is the bespoke contract, often as part of a private finance initiative/private public partnership project.

Usually the programme/variation clauses in bespoke forms are based upon a common standard form, though the process of incorporation can occasionally go awry, rendering the change mechanism at best flawed and at worst inoperable. This is a particular risk where lawyers without the relevant jurisdictional dispute experience are responsible for the drafting (e.g., civil law-based lawyers drafting for disputes under common law).

It is therefore important, prior to signature, for a party to consider the operations of the change mechanism in bespoke contracts to ensure that the requirements imposed on them are fully understood and to ensure that the mechanism functions adequately.

Retrospective analysis of change

Retrospective evaluation of both the financial and programming impact of change (when change has not been agreed during the contract) is a luxury available to the parties after the works have been completed. This is the final route for resolution of disputes over the impact of a change (except, arguably, under NEC3 where retrospective options are severely restricted) and requires the parties or their experts, to establish the actual impact caused by the change.

A retrospective evaluation requires investigation of the actual position and the separation of the impact of other changes from the change under consideration. The process can be complex; hence the role of delay and quantum experts, as well as the many pages in periodicals, books and papers dedicated to arguments over the merits of different types of retrospective analysis.

The principles (i.e., the demonstration of the cause and the effect) remain simple but the value of well-maintained, contemporaneous records and realistic, accurate, regularly updated programmes cannot be over-emphasised. Consider the frequently encountered situation that once a dispute arises, the records, timesheets and invoices are not sufficiently detailed to allow allocation of the direct cost to the change, as the records were simply to provide evidence of the overall cost. Once the project runs drastically over budget, the client starts examining the costs in much more detail, as there is an anticipation that 'surely the 50 per cent increase in cost cannot simply be the result of a few remaining unresolved changes', but he has difficulty knowing without detailed records.

Prospective/live analysis of change

While the process of retrospectively unpicking strands of cause and effect from the final position can be complex, the parties are at least aware of the final outcome. When considering the impacts of change during a live project, analysis usually requires the retrospective analysis to be combined with a projection of future impact. These dual requirements may be defined in the contract mechanism or may simply be necessary in order to report on the status of the project to stakeholders.

Most forms of contract simplify this process by requiring an initial evaluation but allowing subsequent modification to take into account subsequent impacts of the change not originally apparent. Uniquely, NEC3 requires a party to consider the impact to date and then to project forward the future impact and, effectively, to make a new deal for completion of the works including all impacts of the change (subject to a few limitations).

The NEC provisions, while still controversial in some respects, do provide a framework of prudent steps which enable change to be properly controlled and evaluated.

In summary, the key requirements the parties should know and if possible agree on to effectively manage change are:

a) Where they started and were trying to get
b) Where they were just prior to the change occurring
c) When change occurs the parties should:
   i)Identify and notify the change swiftly
   ii) Adequately define the change as quickly as practicable
   iii) Identify the impacts (time, money)

With the movement towards target cost contracts under the NEC forms, it is becoming difficult enough to ascertain the direct costs associated with a singular change, let alone those considered indirect. When forecasting cost associated with a change under the NEC, calculating the impact upon other trades and activities in a reasonable and sensible manner whilst in full flow is nigh on impossible. Let's not also forget that loss of productivity can, in turn, create lengthened project duration with extended site and head office overhead costs too!

How to evaluate impact of a change upon the project

The steps to evaluate the impacts of a change upon a project are:

1) Identify the project programme and budget, which are the most accurate reflections of the agreed contract works at the time and ensure that they have been updated to incorporate the actual status of the project immediately prior to the change occurring.

2) Define the extent of the change itself. Establish an activity or mini programme to describe the change (often referred to as a Fragnet – fragment of a network).
3) Identify the activity or activities within the project programme (item 1 above) that will be interrupted (prevented from finishing), or prevented from starting, or replaced by the change.
4) Impact or apply the fragnet to the project programme. This is likely to require that activities within the project programme are:
   a) Deleted – to be replaced by elements of the fragnet.
   b) Split – creating two activities to cover work done prior to the change arising, and the work that will be completed after an aspect of the change fragnet has been completed.
   c) Unlinked from a predecessor to model the act of the change delaying an activity or group of activities.
5) Examine the updated programme to look for unintended /inaccurate consequences of the change. For example activity chains that have lost their predecessor or successor activities and activities whose sequence have been altered in an unintended way.
6) Time analyse the programme (allow the software to perform its critical path analysis), then compare the impacted programme with the project programme from (1) above and repeat the examination described in (5) above to search for errors and unintended change.
7) Assisted by the above process, prepare a budget for the change as defined by the contract. Typically this will include an estimation of the direct (labour, plant and material) and indirect (fees, head-office overheads, profit, etc) costs identified as resulting from the change as well as any impact upon other elements and activities. The submitted budget for the change will also need to consider the impact upon output levels and resource requirements.
8) Finally, consider the impact upon the key milestones or project completion date between the project programme identified in (1) above and the dates generated from the impacted programme to establish the extent of the impact upon the project key dates.
9) Other changes that have arisen in the same time period as the change under investigation should also be incorporated into the impacted programme to establish whether other sources of impact upon the project dates have also occurred in parallel with the change under consideration.

The extent to which there will be a contractual entitlement to an extension of time or prolongation will depend upon the requirements of the contract and the responsibilities identified for the change and other impacts occurring during the period.

Once the above process is complete, the updated programme and cost submission should be adopted as the most relevant programme and budget (for update with subsequent delays and changes). This may require some modification if the process of agreement of the change requires retrospective modification of the programme presented above (e.g., alteration of the agreed extent of the fragnet programme representing the change).

None of this is exactly rocket science, however failures in the above process are at the root of many disputes.

The extent to which the above are required and the timescales needed for delivery should be defined in the construction contract. It is worth noting that where the parties follow the NEC process for handling change they will not be far from good practice under any circumstances.

Common errors and their sources

Inaccurate baseline

The process of efficiently managing a change is often doomed long before the change has arisen. Commonly this failure occurs in one of two ways (and often in both combined):

1) The original baseline programme or budget is, on investigation, fatally flawed and was never going to be achievable as defined. Therefore, it will not provide a robust basis against which to evaluate the impacts of a change.
2) While the baseline programme or budget may or may not originally have been realistic, the circumstances of the project when the change arose may have diverged from those contracted upon so significantly that the baseline will no longer provide a robust basis for evaluation of the change.

There should be a proverb that states: 'He who cannot say where he is, can make no use of good directions.'

So, the first step required to recover from an inaccurate baseline is to establish

the project status, the actual progress and cost plus any previously agreed change. As most readers who have had the misfortune of being involved with delay experts are probably aware, there are many ways to skin the retrospective analysis cat and even more ways to disagree about the results. Thus the project with either of the problems described above will, by this point, be sliding inexorably towards a dispute.

The lack of an accurate baseline against which to consider change is common because the development and maintenance of a realistic baseline is actually very difficult. It is likely to require a number of project stakeholders to take decisions that they would rather defer or avoid so as to 'keep their options open'. It also requires a consistent level of effort throughout the duration of the entire project, in circumstances that grow in complexity throughout.

Consider the baseline planning for a road tunnel. When planning the works the planning engineers will have an accurate set of information for size and length of tunnel and rate of excavation. Assuming that the ground conditions are broadly as identified, then this element should be straightforward to plan.

There are, of course, often problems that impact upon the ability of the tunnellers to keep to the programme. These may represent contractor risks or require changes to the contract, however, the initial planning should be straightforward.

Delays to tunnelling projects commonly arise in preparing for tunnelling operations or in the installation of systems within the tunnel as and after it is constructed. Consequently these aspects tend to be harder to plan initially and can therefore prevent provision of a useful baseline programme.

The simple fact is that during the preparation of the project baseline programme, the planner will often be unable to accurately estimate the work content for tunnelling enabling work and will not have enough information to accurately or sufficiently plan the systems installation part of the programme. The enabling works aspect usually requires a commercial risk approach to planning such that acceptable level of contingency are provided.

There are some common reasons for failures in baseling planning for tunnel systems:

1) The planner ran out of time before he had finished preparing the baseline so he stuck a bar in at the end labelled 'signalling, comms and power system installation and commissioning'.
2) There wasn't anyone available to give the planner programme information so he stuck in a bar entitled 'signalling, comms, etc'.
3) The systems designers were available to the planner but they weren't due to finish the design of the systems for another six months, so he had to put in a bar labelled 'signalling, comms, etc'.

While these examples are exaggerated, the point is that it is difficult enough to prepare an accurate and realistic programme and budget for works that have been clearly defined. To programme and cost works that have not been defined is, at best, crystal ball gazing.

For tunnelling projects, the other crystal ball element is often in relation to the work required to allow tunnelling to commence. The initial excavation to create access shafts and TBM launch pits often identifies the one utility main not previously identified in the surveys, in a manner not unlike military "reconnaissance by fire". Both processes being similarly noisy, messy and expensive.

Out-of-date baseline

A strength of the NEC contract is its insistence that when a change arises it should be identified, agreed and incorporated into the contract as quickly as possible. In order to deal with this issue, the NEC contract is draconian with regard to the timescales for dealing with compensation events.

That being said, often the reality under NEC or other forms is that neither party has managed to comply with its roles or time limits. Hence, over an often surprisingly short period, the contract mechanisms will have *de facto* ceased to be meaningful. The element that often manifests this problem is the foundations required for evaluation of change, the updated baseline.

This is the second common failure identified above – the failure to maintain an accurate programme for the works, updated to incorporate actual progress (or the lack thereof) and agreed changes to the scope of the works remaining.

While NEC3 is referred to above as an example, the issue of failure to adequately maintain the project baseline applies equally to the consideration of change under any contract where the incorporation of changes to the works is allowable.

We return to the point that, in order to be able to evaluate a change (actual or potential) the actual status of the project at the time the change is identified must be known. Similarly, the planned route from that point to completion should also be known.

Some forms of contract are not specific that an agreed and up to date project assessment is required in order to establish the likely impact of a change, it is generally accepted (ref 1) that in order to prove the impact of a change, then the impact or likely impact on the previously projected end date for works needs to be demonstrated.

The NEC contract requires that the identified change (via the compensation event mechanism) is evaluated against the current status of the project in order to establish the impact or otherwise of the change upon the predicted completion targets.

Other contracts require a similar projection but will allow a revisit of this estimate after the works are complete in order that the actual impact of the change is fully addressed.

Evaluating the impact of the change

Evaluation of change should be as swift as practicable. There are a number of reasons for this:

1) To allow the project to accommodate the change as quickly as possible.
2) To ensure debate between parties regarding the impact of change is possible while the circumstances are fresh.
3) To limit the impacts of the change itself and avoid 'disallowed' costs.

In order to achieve this result the parties will need to identify, define and notify the circumstances of a change clearly. They will then need to establish the details of the change and seek to correctly identify the linkages between the change and the previous programme and to budget for the works. With this information the project team should be able to link the change to the previously accepted programme and budget so as to establish the impacts of the change upon the project programme and anticipated final cost.

In parallel with this process of evaluation, responsibility for the change and its implementation must also be allocated and agreed. If this process has

been followed then the change should now have been defined and incorporated within the revised and agreed project programme. The cost and time impacts should also have been agreed and the actions necessary to implement the new project programme should have been allocated.

The change will therefore have been incorporated into the contract works and its impacts allocated contractually. Where the NEC contract is in use this should, in most circumstances, be the conclusion of the issue save any pain/gain share calculations. For non-NEC contracts the actual impact of the change may need to be revisited to ensure that the delay caused by the change did not exceed the originally agreed amount.

Finally, the change should be continually monitored and recorded in detail throughout the duration of the project for both internal and external purposes, as this may well affect targets and incentive mechanisms. The measured mile and similar other demonstrations of loss have problems finding reference points unless timesheets record sufficient detail to distinguish them from the baseline and 'disallowed' costs can be difficult to identify. More commonly we are provided with records of simple monthly payments into 'salaries' or such like on the contractor's cost ledger, rather than accurately detailed records/diaries.

The unresolved change

Any link in the chain that is missed is likely to obstruct the clear evaluation of a change and contribute to disagreement between the parties on the impact of change. Inevitably these difficulties will increase as the lack of agreement causes the impact of the disputed change to magnify while responsibility for the change is unallocated.

Where responsibility for change is unallocated then the project will, to an extent, be lacking agreed project targets. In such circumstances the impacts of a change will remain unrestrained. If the parties have no specific agreed responsibilities to incorporate the change into the project then it is very likely that the time and cost impacts will continue to grow.

Consider a simple example:
A TBM launch pit is delayed by issues including delays to realignment of utilities.

Where responsibility can be identified or allocated, the delivery of the TBM can be re-scheduled. Alternatives for acceleration can be explored and unnecessary acceleration of, say, a client change to a signalling design can be avoided. Further, a contractor's concrete defect in a reception chamber wall can be resolved without consequential acceleration by the contractor.

Where responsibility cannot be identified the parties will face:

1) a dispute over the delay to the launch chamber,
2) an additional cost for storage of TBM pending completion of launch chamber (added to disputed costs for 1 above),
3) cost to accelerate works associated with the signalling design change unnecessarily (cost to the Client),
4) cost to mitigate the contractor's receiving chamber concrete defect can be minimised.

Alongside these simple consequences of an unallocated change flow the more subtle consequences that arise from a project limping forward with an extant dispute and without an agreed programme to completion.

Conclusions

The above article should therefore have demonstrated that the process of evaluating the time and cost impacts of a change are comparatively straightforward to describe. However, it should also be clear that the process often fails to yield agreement to the results because there is no suitable baseline or reliable progress record available. This is equally applicable to both time and cost.

This is why all parties to a project are advised to ensure that for all aspects of the project they:

a) ensure that an adequate baseline is established,
b) maintain the baseline incorporating changes and actual costs/progress regularly and accurately,
c) identify and notify the change swiftly,
d) define and agree the change swiftly,
e) identify and agree the impact swiftly.

These are indeed simple steps. However the requirement to start with, and to maintain a realistic and accurate project programme and budget is rarely achieved. Successful control of change is heavily dependent on the parties' approach to the maintenance of the project programme and cost forecasts. Too often these fail long before the change at issue is ever contemplated. Inevitably, when the basis for evaluation is lost, successful and timely management and incorporation of change will also be lost.

As to prevention of these failures:

1) Support the team preparing the baseline to ensure that the best information possible is provided to them.
2) Ensure that, where the planning team has been required to make a guess, that the parameters of those guesses have been understood fully and commercially addressed.
3) Ensure that the baseline planning team have a spread of skills to plan the entire project not just the Civils or the Systems.

In terms of cost, undertaking good reporting procedures will help assess the impact once a change is identified. This should include:

1) the identification of the actual cost to date referenced and recorded against actual progress to date when the change occurs,
2) the measurement and identification of these costs against the baseline programme,
3) establishing a separate activity/cost code within cost ledgers/accounting procedures to capture all costs associated with the change,
4) recording cost and progress impact using an Earned Value Management (EVM) technique.

In order to ensure that the programme remains sufficiently current both the contractor and the engineer/project manager must perform. Therefore a process of agreement of progress records is significant, though the contractor should also:

1) allow adequate planning resource for the works,
2) make the reporting and maintenance of programme records a management priority,
3) avoid the temptation to modify the programme as a contractual claims tool (this approach is usually counterproductive as the programme is more likely to be challenged).

Simple really…

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1. See for example Balfour Beatty Construction Ltd v LB Lambeth [2002] EWHC 597 (TCC) "By now one would have thought that it was well understood that, on a contract of this kind … the foundation must be the original programme (if capable of justification and substantiation…)"

A consultant and a gentleman

"I knew I wanted to be a civil engineer when I was 10 years old," says Alastair Biggart, currently an Independent Tunnelling Consultant (ITC) to the New Metro North Project in Dublin and the Hallandsas Project in Sweden. "My boss and mentor was Jim Buchanan of Sir Robert McAlpine who gave me a lot of help in learning the practical aspects of tunnelling. However an even stronger reason was that my father was a tunneller and with his cousin owned Mitchell Brothers Sons and Company, who were a specialist tunnelling contractor."

Alastair earned his degree in Civil Engineering at Loughborough University in the 50s. Afterwards, his national service was spent in the RAF as a pilot. He then spent four years working for three different contractors, six years with Mitchell Brothers, followed by 12 years with Edmund Nuttall. He joined Lilley Construction in the early 80s as a technical director working on the Cairo Wastewater Project. In 1992 Alastair had a career shift, moving from contracting into consultancy and joined Mott MacDonald to work on the Storebaelt Eastern Tunnel Project.

He retired from full time work in 2001, though this hasn't stopped him. "I have enjoyed every minute of it," he says. For the last 11 years as an ITC, he has worked on 18 different projects all over the world, a key reason for his enjoyment. "I have always enjoyed every aspect of tunnelling […] because of the large variety of work and the continuing challenges." He adds, "I have not found it stressful as I was largely not acting in a management role, but also because I have never suffered from work related stress."

Alastair began work on the Hallandsas project in 1999 and has for the majority of this time visited the project every couple of months. He has given advice largely on technical matters, but also organisation, health and safety and, early in the project, advised on the type of TBM to be used. He joined the Dublin Metro North project a year ago, which he normally visits on a monthly basis.

He advises on the use of closed face TBMs and tunnelling in general, including settlement control, vertical alignment, submittals, risk registers and interfaces. He also attends technical workshops for bidders. "Fortunately my wife, Mary, likes travel so she has very often come with me," he says.

Does he have a favourite moment from tunnelling? He wryly points out that he is more used—from interviews for work—to being asked if he has any 'horror stories' and how he has coped with them. "I have been fortunate and have not been involved in any disasters," he says. "However an 'unfavourite' moment was when I was working on the Cairo Watewater project back in 1986. I stayed too long in the compressed air and ended up with the bends, not an experience I recommend.

Biggart is consultant to the Hallandsas project in Sweden

Above: **Alastair Biggart with the TUCSS president Ow Chun Nam**

On the other hand, you know what they say: 'you are not really a rider unless you have fallen off your horse at least once.'" He does have a treasured moment, however: the memory of the Channel Tunnel breakthrough and 50 British tunnellers charging through to the French side to selflessly help them drink their wine and smoke their cigars. He reflects that the French have "slightly different safety rules from us."

So what is next for Alastair Biggart? "Who knows? […] I don't go looking for new work, but if I am asked and it sounds interesting I may take on a new project. If it all finishes in the near future, then I shall just have to write a book about some of the more interesting projects I have worked on," he says. "On the other hand I may just help on the farm on which we are now living with our daughter, son in law and their four children. I am fascinated to find that the mechanical sweeping arrangements for the cow sheds for the 350 cows work on exactly the same principle as the segment feeder in a TBM!"

"I have never for a moment regretted my 34 years as a contractor and now my 18 years as a consultant and a gentleman. I have been very fortunate and have worked with many inspiring engineers, including John Bartlett of Motts, Richard Triggs of Nuttalls and Jim Buchanan of McAlpine."

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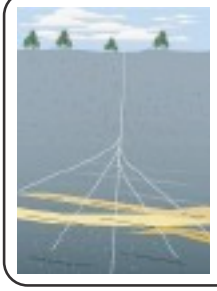
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29 - 30 JUNE 2011
Underground Construction Conference and Exhibition, London
The eyes of the global tunnelling industry are swivelling towards the UK with some of the world's largest underground construction projects getting underway. Event includes: technical and design developments in underground construction, tunnel operation and maintenance, sustainable development and minimising the impact of underground works, a world wide tunnelling perspective, UK projects - today and the future, ground investigation, treatment and monitoring.
Tel: +44 (0) 207 973 6695
Email: g.stringer@hgluk.com
Website: 2011.tunnellingshow.com/

12 - 16 SEPTEMBER 2011
6th International Symposium on Sprayed Concrete, Tromso, Norway
Main themes will be design, construction and durability of wet-mix sprayed concrete in underground structures. The Norwegian Concrete Association is currently revising the Publication No. 7, Sprayed Concrete for Rock Support. This will be debated during the symposium. Contact: Siri Engen Email: siri engen@tekna.no Website: www.sprayedconcrete.no

26 - 27 OCTOBER 2011
XI International Conference Underground Infrastructure of Urban Areas, Wroclaw, Poland
A forum to develop an exchange of experiences and provoke a discussion on the topics related to building of tunnels and underground infrastructure in cities.
Tel: 0048 71 320 29 14
Email: andrzej.kolonko@pwr.wroc.pl

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Editor, 'Tunnels & Tunnelling International', Boundary House, 91-93 Charterhouse Street, London, EC1M 6HR, United Kingdom.
Fax: +44 20 7936 6826
Email: editor@tunnelsonline.info
Web: www.tunnelsonline.info

BRITISH TUNNELLING SOCIETY

20 JANUARY 2011: **East Side Access Project, New York**
The USD-7.3bn East Side Access Project currently under construction in the heart of Manhattan by the New York Metropolitan Transportation Authority Capital Construction Company is the largest federally funded infrastructure project in the USA. This talk will also present an overview of the multitude of tunnelling methods being used, including the first use of slurry TBMs in New York to excavate the 50,000 linear feet of tunnel.

17 FEBRUARY 2011: **Lesotho Highlands Tunnels - BTS / MinSouth Joint Event**
The Ingula Pumped Storage Scheme is the largest tunnelling project in South Africa. The location is just south of Johannesburg and just north of Lesotho. 12 km of 9.4m dia tunnels, 4 shafts (20m dia x 150m deep), 2 caverns, 200m x 20m spans.

17 MARCH 2011: **Green Park Step Free Access**
The works included a south-eastern extension to the existing ticket hall incorporating a ramp from the adjacent Green Park directly into the station, and the installation of two lift shafts. This presentation will discuss the development of the design and construction of the elliptical lift shaft and stub tunnel using SCL methods & escalator jacking system and the instrumentation and monitoring equipment employed.

21 APRIL 2011: **Harding Prize Competition**
The Competition is open to all aged 33 or under at the end of 2010. Entrants must submit an original paper relating to any aspect of tunnelling which they consider of interest to those in the tunnelling industry. The closing date for submission of papers is 28th February 2010.

19 MAY 2011: **BTS AGM + Limerick Immersed Tunnel**
The Limerick Tunnel will provide a new road crossing under the River Shannon The tunnel comprises five 100m long immersed tunnel elements, a cut and cover tunnel and approach ramps on each bank.

16 JUNE 2011: **High Speed Railway Tunnels in Spain**
Three separate major tunnel projects in Spain.

15 SEPTEMBER 2011: **Crossrail**
Latest developments on this major London project.

20 OCTOBER 2011: **BTS / BGA Joint Event - Ground Reference Conditions & Geotechnical Baseline Reports**
Details of presentation to be announced.

contacts

Jon Young

EDITORIAL

EDITOR
Jon Young
Tel: +44 20 7336 5256
Email: jon.young@tunnelsandtunnelling.com

TECHNICAL EDITOR
Maurice Jones
Tel: +44 1296 397 353
Email: maurice.jones@tunnelsandtunnelling.com

AMERICAS EDITOR
Nicole Robinson
Tel: +1 612 9402 780
Email: nicole.robinson@tunnelsandtunnelling.com

Maurice Jones

NEWS EDITOR
Alex Conacher
Tel: +44 20 7336 5257
Email: alex.conacher@tunnelsandtunnelling.com

EDITORIAL SECRETARY
Tasha Denney

REGULAR CONTRIBUTORS
Adrian Greeman, Bernadette Redfern, Patrick Reynolds

PRODUCTION & DESIGN

DESIGNER
Natalie Kyne

TECHNICAL ILLUSTRATOR
Nick Stenning

PRODUCTION CONTROLLER
Loraine Lee
Tel: +44 20 8269 7799 Fax: +44 20 8269 7840
Email: llee@progressivemediagroup.com

Nicole Robinson

ADVERTISING

HEAD OF SALES
Shelly Palmer
Tel: +44 20 7936 6848
Email: shelly.palmer@tunnelsandtunnelling.com

EUROPEAN SALES
Randolf Krings
Tel: +49 611 5324 416 Fax: +49 611 5324 519
Email: t&t@emcmedia.de

NORTH AMERICAN SALES
Clive Bullard
Tel: +1 845 231 0846
Email: clive.bullard@tunnelsandtunnelling.com

CLASSIFIED AND RECRUITMENT
Tom Willard
Tel: +44 20 7936 6843
Email: tom.willard@tunnelsandtunnelling.com

ITALIAN SALES
Ediconsult
Tel: +39 02 477 10036 Fax: +39 02 477 11360
Email: milano@ediconsult.com

Shelly Palmer

HEAD OFFICE: **World Market Intelligence**
John Carpenter House, 7 Carmelite Street,
London EC4Y 0BS, UK
WEB ADDRESS: www.tunnelsonline.info
EMAIL: editor@tunnelsonline.info
TEL: +44 20 7336 5256
FAX: +44 20 7936 6813

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