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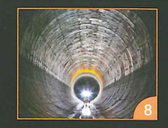
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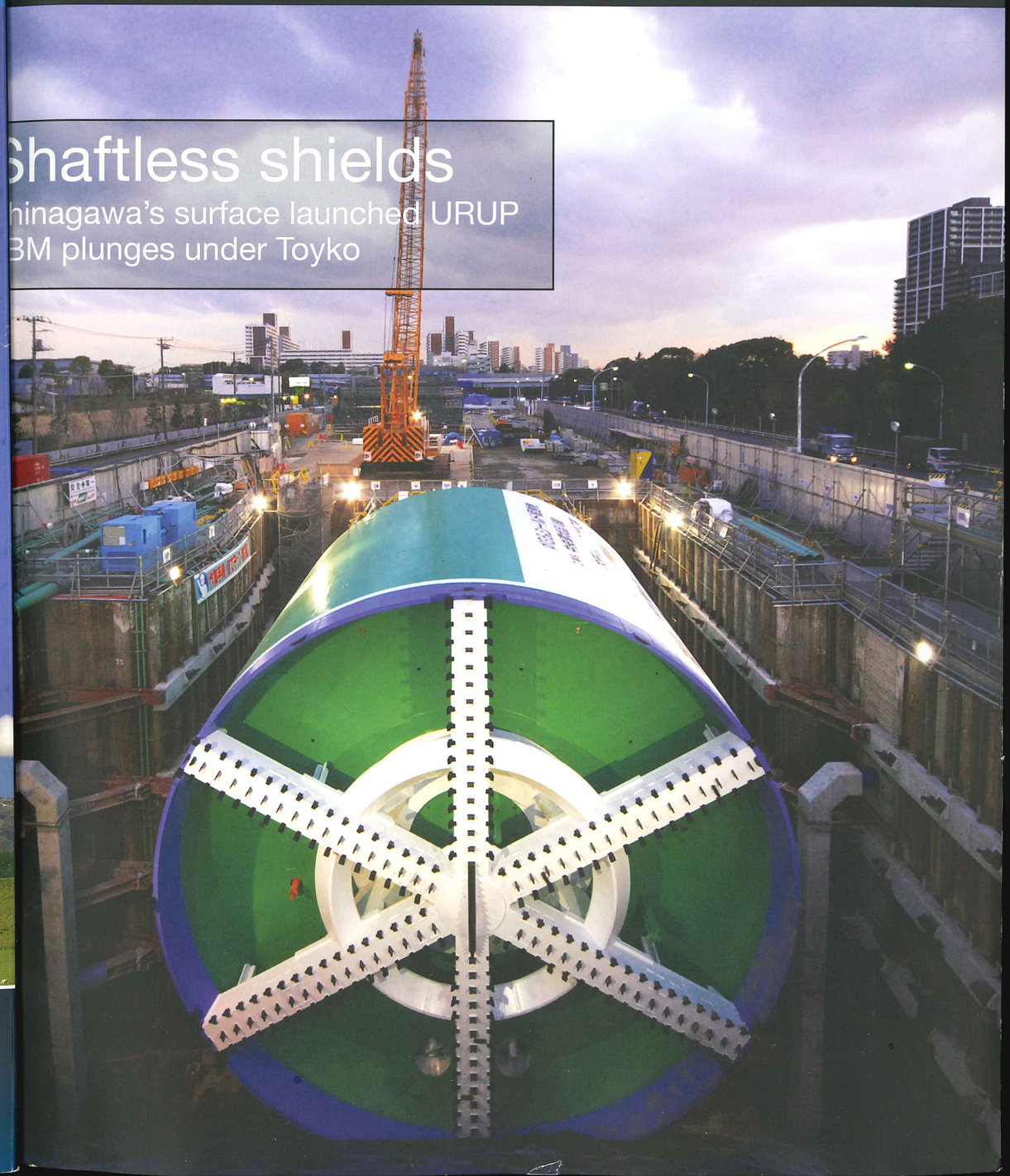
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Ancient tunnelling
A 6th century BC dictator's legacy, brutal working conditions and ancient instruments

Hand mining
Debates over the real risk of vibration, finding the tools for the job and a look at the law



Shaftless shields

hinagawa's surface launched URUP
BM plunges under Toyko

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SPAIN



SAFELY PASSED BENEATH SAGRADA FAMILIA.

The tunnel specialists from UTE LA SAGRADA mastered a very special challenge as part of the "Túnel del AVE Barcelona Sants-Sagrera" project. An almost 5 kilometer long railway tunnel (interior diameter 10,400mm) was excavated beneath Barcelona's city center. A partial section beneath Calle Mallorca merits special attention: the route runs next to the foundations of "Gaudi's Sagrada Familia", a UNESCO world heritage site and pride of the Catalans.

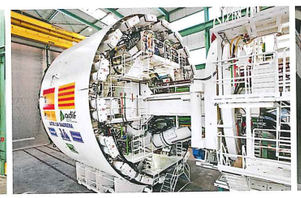
With the help of "Barcino", the Herrenknecht EPB Shield S-450 (Ø 11,520mm) the jobsite crews safely excavated the tunnel without causing any impacts on the surface. On July 26, 2011, all involved in the project celebrated the successful breakthrough into the target shaft close to Sants main station.

This was an important milestone for the client ADIF to connect the Spanish railway network to France and Europe. As of 2010, Spain has the longest high speed railway network in Europe. Almost 20 tunnel projects with a total of more than 145 kilometers of new routes have been realized or are still under construction using Herrenknecht technology – both beneath cities and through the mountain ranges of the Iberian peninsula.

BARCELONA | SPAIN

PROJECT DATA	CONTRACTOR
S-450 **EPB Shield** Diameter: 11,520mm Cutterhead power: 6,300kW Tunnel length: 4,849m Geology: sand, gravel, hard clay	UTE LA SAGRERA (Grupo SACYR, S.A.)





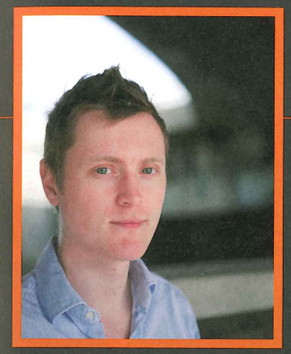


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On shaky ground

In this issue of *T&TI* we are running an article on the challenges faced at the dawn of tunnelling in 6th century BC Greece, as well as a focus on the latest developments in the Asia Pacific, the final paper from the three Harding Prize finalists (this month by Spyridon Konstantis) and technical reports covering hand mining and its alternatives, and EPB shield spoil conditioning.

It seems a good issue, like any other. But, little did we realise that an investigation of one of these topics would be treated with much suspicion and even fear. Contractors and consultants alike, on big projects and small would volunteer an opinion, in some cases an observation spanning decades, only to add 'but don't put my name to that'.

I am referring to Hand-Arm Vibration Syndrome (HAVS).

Few outside of the UK Health and Safety Executive (HSE) have been willing to speak openly and reportedly on the topic. It feels clandestine and something is very, very wrong if members of a learned society feel unable to contribute to a reasoned discussion on an issue that even the chairman of the BTS says we do not know enough about.

The issue is not a new one, merely one we have stirred up in the course of our investigations. The subject has been debated hotly in closed committee rooms. The reluctance to speak out against HAVS seems to stem from the HSE's decision to make it an enforceable offence less than 10 years ago. No contractor wants to risk falling foul of the HSE.

But off the record many tell *T&TI* that HAVS is not a concern for tunnellers, that there has never been a tunneller suffering from the syndrome (tell us if you know of one). BTS chairman Bob Ibell has called for more research into the subject, in an attempt to shed further light on the issue. While the HSE believe further research would not be cost effective – so stick to the rules as they are.

There are many issues in the industry that are hard to speak openly about. Perhaps this would be a good time to suggest the re-introduction of a too-long neglected section of *T&TI*: 'The Drifter' - items written anonymously to protect the good name of the author, often on important subjects or positions considered too controversial, non-PC, or in some other way, career-'Kryptonite'.

Any takers?

Meanwhile, from the haze of shuffling feet, clarification of party lines and covert tip offs that belong in a crime thriller, *T&TI* presents what it has learned of the HAVS 'debate'. Turn to page 32 to begin…

Jon Young with Alex Conacher and Maurice Jones

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Basic tunnelling still a viable method

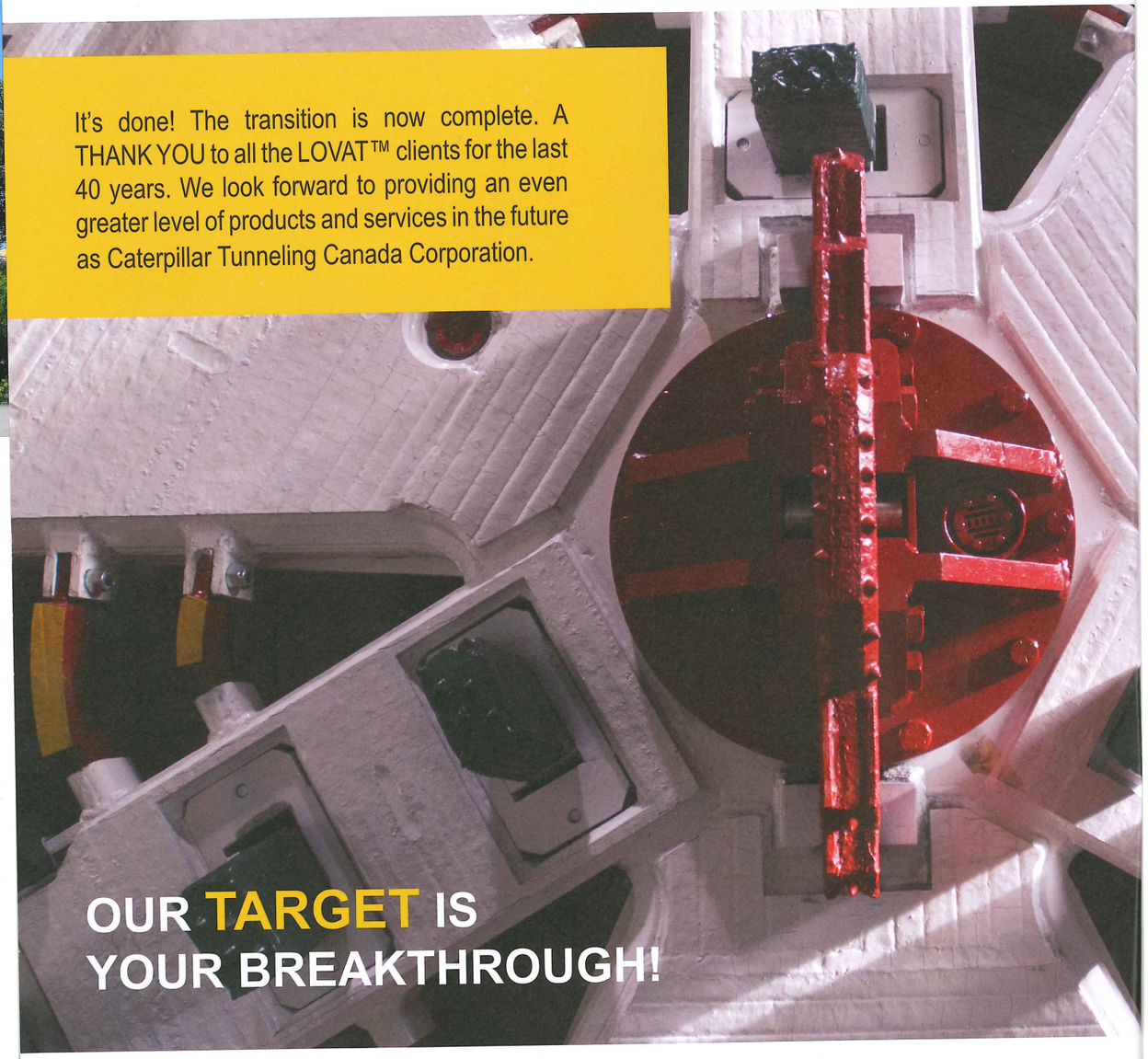


On the cover:

Hitachi Zosen TBM as it readies to launch on a shaftless drive in Toyko, Japan

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St Petersburg 19.25m TBM order

RUSSIA

The concessionaire for the planned Orlovski road tunnel (Nevskaya Concession Co - NCC) under the River Neva in St Petersburg, Russia, has ordered a 19.25m-diameter Herrenknecht Mixshield TBM.

On signing the order in St Petersburg, Russian Prime Minister Vladimir Putin took the opportunity to familiarise himself with the major highway project, the key place of the giant Herrenknecht Mixshield within it, and the operation of such a TBM.

The PPP-project under Russian government decree is planned to provide a 24-hour crossing for traffic in St Petersburg under the River Neva between the city centre and the northern districts and the orbital motorway. This will allow a continuous passage for ships passing through from the Baltic/Volga Waterway, whereas previously a series of lifting bridges had interrupted free passage during the shipping season.



Above: Russian Prime Minister Vladimir Putin (left) meets with Herrenknecht chairman Martin Herrenknecht (right)

The tunnel bore will be over 1km long through mainly soft fluvial deposits under high groundwater pressure (see *T&TI* News In Depth, March 2011, p14). It will carry two, three-lane carriageways on two levels, substantially increasing overall cross-river traffic capacity.

Including the trailing back-up equipment, the mixshield will be 82m long. The TBM itself will weigh 3,800t and deliver 8,400-kW of drive power to the cutterhead, allowing excavation of 600m³ of spoil per hour. Herrenknecht has previously said that the Schwanau factory was ready to begin manufacture as soon as the order was received. Tunnelling is scheduled to begin in the spring of 2013 for operation in 2016.

Other companies understood to be involved in the Orlovski Tunnel project so far include Danish consulting engineers COWI, the JSC Institute 'Stroyproekt' of St Petersburg, PSP Consulting Engineers, Poyry, Mott MacDonald, Freshfields Brukhaus Deringer and the Russian Research & Design Institute of Regional Development & Transportation.

Malaysia to tackle corruption

MALAYSIA

Contractors bidding for Malaysian Mass Rapid Transit (MRT) projects will be answerable to the Malaysian Anti-Corruption Commission (MACC).

A new 'Integrity Pact' agreement was presented last month to contractors at the MRT pre-tender briefing. It warned that companies could be de-registered or have their tenders terminated.

The announcement comes as the industry reveals the scale of its dependence on bribery. In a weekly opinion poll carried out by *T&TI* last month more than half of the respondants said that bribery was a necessary part of conducting business in the international tunnelling market.

State-owned infrastructure client Prasarana said that MACC's presence at the briefing was the first time in history such steps had been taken against corruption. Encik Abdul Malik Azman, Prasarana head of MRT procurement, said that contractors would be required to sign the Integrity Pact upon submission of tender applications, then sign again with Prasarana following the contract award.

"Both Prasarana and the contractors must adhere to conditions set upon by the Integrity Pact," said Datuk Hajah Sutinah Sutan, MACC deputy chief commissioner, prevention. "Be warned that Prasarana is firmly committed to the IP and will report to us at MACC if there are any attempts of bribery by any of the contractors."

She added that the construction industry has been one of the biggest culprits or bribery, now a criminal offence.

"It's also an offence for contractors to pay out their rivaling contractors to withdraw their bids to win contracts. Offenders could fail jail sentences up to 10 years; or be fined not less than five times value of their bribe; or fined MYR 10,000 (USD 3,357), whichever is higher; or both."

The Government is evaluating contractor pre qualifications for underground works.

Poll reveals scale of bribery



Alaskan Way presses on

USA

The Federal Highway Administration signed a record of decision last month allowing the Washington State Department of Transportation (WSDOT) to begin final design and construction of the 1.7mile (2.7km) tunnel beneath downtown Seattle.

Following issuance of the record of decision, WSDOT directed Seattle Tunnel Partners (STP), a joint venture of Dragados USA and Tutor Perini, to begin work on the second phase of its USD1.35bn design-build contract for the 57ft (17m) diameter bored tunnel.

The decision follows a hotly contested mail-in election on 16 August, where the citizens of Seattle voted (59 per cent) to support ordinances passed by the City Council regarding agreements with WSDOT on right-of-way among other issues.

Tunnellers call for collapse investigations

GLOBAL

Tunnellers have called for all collapses to be investigated by an external party.

In many countries a third party routinely investigates only fatal collapses, usually a government-appointed safety body. In some countries, such as China, it takes multiple fatalities to trigger an external investigation.

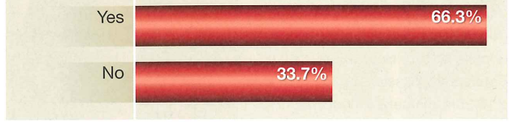
In an online opinion poll carried out by *T&TI*, respondents voted two thirds in favour of non-fatal collapses also being investigated by an external body.

The results go against the views held by the heads of industry organisations. Speaking off the record, several organisations told *T&TI* they would neither want to take on the role of investigating the collapses nor believe that the investigations should be conducted.

Immediate past president of the International Tunnelling Association (ITA), Martin Knights, said, "I don't necessarily agree that an external party should be brought in. It depends on the degree and extent of the collapse and whether property was damaged. If property was damaged then third or external parties would necessarily be involved for insurance, loss adjustors, etc." He added, "On balance I would vote no (not necessarily), but the degree of collapse would influence the need to involve others."

But there are benefits to the industry as a whole in having collapses fully investigated and the information disseminated. Former UK Health and Safety Executive principal specialist inspector of health and safety in civil engineering Donald Lamont said: "The HSE has the power to investigate as any collapse would have health and safety implications." But he added that the only international body is the ITA, which has no investigatory powers whatsoever.

T&TI online poll: Should an external party investigate all non-fatal tunnel collapses?



Motts and Arup split Kowloon

AUSTRALIA

Arup and Mott MacDonald were awarded a contract to design and supervise construction of the Central Kowloon Route (CKR) in Hong Kong.

A 3.9km rock tunnel and a section of underwater tunnel will be required under the CKR scheme, as well as cut and cover tunnels and interchanges. Project responsibilities were split evenly.

KM Yeung, managing director of Mott MacDonald Hong Kong said, "This highway and tunnel scheme will be a strategic part of Hong Kong's Route Six highway network and will be key to relieving traffic congestion in Kowloon."

Arup director and East Asia highways business leader David Pegg said, "We are delighted to win another major infrastructure project in Hong Kong."

Pegg said the company's experience makes it "uniquely placed to deliver this strategic highway that will maximise social and economic benefits with positive impact on the daily lives of the local community."

Sicily power transfer

ITALY

Seli will execute a project to bring clean energy to Sicily from the Italian mainland. Italian electricity company Terna awarded the EUR 38M contract for the excavation of a 2.8km sub-horizontal tunnel, 7m-diameter, 353m-deep vertical shaft and associated works.

The double shield TBM used will be 4.09m in diameter and will be tooled to allow an extra 50mm excavation diameter.

Two sets of cables will travel from the Favazzina marine harbour in southwest Italy to Sicily. Excavation will begin in May 2012.

Panama Metro contractor gets TBMs

PANAMA

The FCC-led consortium responsible for building the first line of the Panama Metro took delivery of two TBMs at a ceremony in Herrenknecht's hangers in Schwanau, Germany.

The nearly 10m in diameter TBMs will arrive in Panama separately by November to bore the 7km tunnel of Panama Metro's Line One.

The project, which was awarded to a consortium of FCC and Brazilian company Odebrecht, has a budget of more than EUR 1bn (USD 1.4bn).

At the delivery ceremony Ricardo Martinelli, President of the Republic of Panama, announced the tender for Line 2 of the Panama Metro.

He said, "We are going to transform the former transport chaos in Panama into a safe, reliable system for all citizens."

News in brief

Polish rail contract awarded for refurb project
Polish Railways and the Municipality of Lodz awarded a EUR 350M (USD 493M) contract for Phase II of the Warsaw-Lodz rail line modernisation project and the Lodz Fabryczna underground station to a partnership led by Astaldi. The underground station comprises a double tunnel and double track of 1.5km; four platforms and eight tracks; plant and superstructure of the entire stretch. The project is estimated to last 42 months, including design, which will start immediately.

Tennessee city seeks tunnel expansion funds
Officials in the City of Chattanooga are planning an upgrade to the Wilcox Tunnel, constructing a new, two-lane eastbound tunnel and retrofitting the existing tunnel as a wider, one-lane westbound tunnel. The USD 42M project relies on up to USD 25M being secured in a federal TIGER Three grant.

Australia's biggest box jack completes

AUSTRALIA



Thiess successfully jacked a box the size of a rugby field as part of Brisbane's Airport Link project in Queensland, last month. This was the largest box jacking undertaken in Australia.

"Traditional methods of tunnelling would have required up to 30 weekend track closures, affecting freight, city network and AirTrain customers," said a Thiess spokesman. The box jacking operation, where two purpose-built concrete boxes were pushed and pulled beneath the rail embankment in Kalinga Park, was successfully completed without any disruption to rail services.

The spokesman said, "As one of the most complex engineering aspects of Airport Link's construction, the jacking of the giant boxes was required to form part of the project's road tunnel.

"Before jacking work could begin, 48 canopy tubes were pushed through the embankment to form a platform providing stability to the North Coast Railway Line. The concrete boxes were then constructed beside the railway line, before hydraulic jacks and steel strands were used to push and pull the boxes through the rail embankment."

The boxes were 65m long, 12.5m high and had a combined span of approximately 38m. They were pushed 55m into position beneath the railway embankment.

To maintain stability of the rail embankment the work was done continuously for 864 hours.

Maryland consultant named

USA

Maryland Transit Authority has selected a joint venture of Parsons Brinckerhoff and RK&K (PB/RK&K), in association with Aecom, as an on-call general engineering consultant for statewide transportation projects.

Under this contract the joint venture will provide project management, project controls, environmental, structural, tunnelling, rolling stock and train signal engineering services during the preliminary and final design phase of any open-ended transportation project in the state.

PB/RK&K's principal assignment is designing the proposed Red Line, a 14-mile (22.5km) light rail system that would extend from Woodlawn in Baltimore County into Baltimore City, through downtown Baltimore, and terminate at the Johns Hopkins Bayview Medical Center Campus.

This alignment includes five underground stations, 15 surface stations, one mile of aerial structure and approximately four miles (6.3km) of dual-track tunnel.

Final design for the Red Line light rail is expected to be completed by 2016.

HATS off for Hong Kong effluent award

HONG KONG

The Hong Kong Drainage Services Department (DSD) awarded a HKD 680M (USD 87M) contract for an 8.5m internal diameter, 880m-long tunnel as part of the Harbour Area Treatment Scheme (HATS) 2A sewer project.

Chan Chi-Chiu, director of drainage services for DSD said the contract, which also includes disinfection facilities at Stonecutters Island, is scheduled for completion in early 2015.

"The tunnel will serve to convey the treated effluent from the Stonecutters Island Sewage Treatment Works to an existing outfall drop shaft and provide sufficient retention time for disinfection." He added, "The effluent tunnel will be constructed in a rock layer at a depth of 90m such that it would not constrain the development potential of the land above the effluent tunnel."

Drill and blast will be used to excavate the project.

News in brief

Boring for US Big Dig void
Borings will be made next month to study a void that formed under one of Boston's Big Dig tunnels and to determine how to fill it.

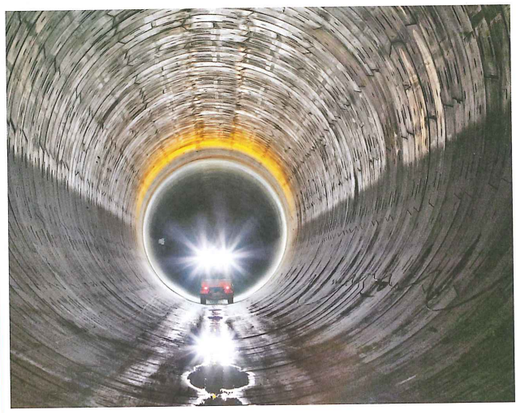
Drilling for North West Rail
Geotechnical work on New Southwale's North West Rail Link was launched last month. Over the coming months around 150 bores will be drilled to depths of up to 75m along the proposed 23km long rail route, in Australia.

One in five lack the tools for the job

T&TI online poll: Are you equipped with the tools to do your job safely?



Portland CSO tunnel nominated for OCEA



Left: The completed east tunnel; photo by Sue Bednarz and Portland Environmental Services

USA

The American Society of Civil Engineers (ASCE) has announced Portland's Willamette River CSO Tunnel Program as one of the five finalists for the 2012 OCEA (Outstanding Civil Engineering Achievement Award).

Part of Portland's 20-year program to control combined sewer overflows (CSOs), the project consisted of constructing tunnels on both sides of the Willamette River, several tunnel shafts and connecting pipelines, two pressure sewers and a large pump station.

Annually, ASCE recognises a project that "best illustrates superior civil engineering skills and significantly contributes to civil engineering progress and society." The winner will be announced at an award ceremony in Washington, D.C., next March.

Two slurry pressure TBMs were used to construct the 3.5-mile (5.6km) long, 14ft (4.3m) diameter West Side CSO tunnel, at depths ranging from 100ft to 150ft (30.5m to 45.7m). This was completed in variable ground conditions below the water table. Another slurry pressure TBM mined the six-mile (9.7km) long, 22-foot (6.7m) diameter East Side CSO Tunnel.

Key players in the project include: contractor joint venture of Impregilo/S.A. Healy for the West Side CSO tunnel; contractor joint venture of Kiewit–Bilfinger Berger for the East Side CSO; Parsons Brinckerhoff for design and Jacobs Associates for construction management.

As of summer 2011, the city was in the process of activating the USD 293M west and the USD 426M east tunnels "ahead of schedule and under budget."

News in brief

Russia wants to tunnel to the United States
An underwater rail tunnel connecting Russia to the U.S. bored under the Bering Strait has received endorsement from Aleksandr Levinthal, deputy federal representative for the Russian Far East, at a conference last month. The 105km tunnel is estimated to have a potential completion date of 2045.

Train service scheduled for Gotthard tunnel by 2016
The Federal Office of Transport (FOT), AlpTransit Gotthard Ltd and Swiss Federal Railways have said they will do everything possible to make the Gotthard Base Tunnel operational from December 2016. After a detailed analysis of making the tunnel operational one year earlier than planned in 2016, the FOT said starting scheduled train services from the end of 2016 was "realistic, feasible and appropriate," and that currently no apparent problems would prevent this.

Hindhead circuit at full throttle

GREAT BRITAIN

The Hindhead tunnel fulfilled an unseen purpose as it became the UK's newest race track for a catalogue of high-performance cars. The tunnel built to divert traffic away from the homes of locals has resulted in dismay as 'wealthy, young drivers' scream through, over and over, to break their own lap times.

Locals said the Hindhead tunnel at night was a 'dangerous no-go zone.' Local resident William Broadhurst said, "they're turning up in their souped-up cars so they're obviously not just young drivers. They are brainless, mindless thugs."

Neighbourhood specialist officer for Surrey Police, Jason Clifford, said, "it would appear that the enthusiasts are keen to experience the longest under-land road tunnel in the United Kingdom and for some this has led to some extreme driving practices.

"Surrey Police will not tolerate anti-social driving and has, as a direct result of reports and complaints from local residents, set up specific taskings to tackle the behaviour."

The GBP 371M (USD 598.3M) Hindhead tunnel opened on 29 July on time and on budget. It was hailed as a success all round from a construction point of view. When it opened, project designer Mott MacDonald predicted a flow of 30,000 vehicles per day.

India gets blasting on longest road tunnel

INDIA

Engineers executed the first blast on India's longest road tunnel on Friday.

Australia-based Leighton Welspun Contractors kicked off construction work on the INR 26bn (USD 565.9M) Chenani-Nashri road tunnel project on the Jammu-Srinagar highway in Udhampur district, Jammu and Kashmir.

Work will include a 9km, 13.3m-diameter two lane main tunnel. A parallel escape tunnel will also be constructed with a diameter of 5m.

The tunnel will be 1,200m above sea level with overburden of up to 1km and will be constructed using NATM. The twin tunnels project will be completed within a period of five years.

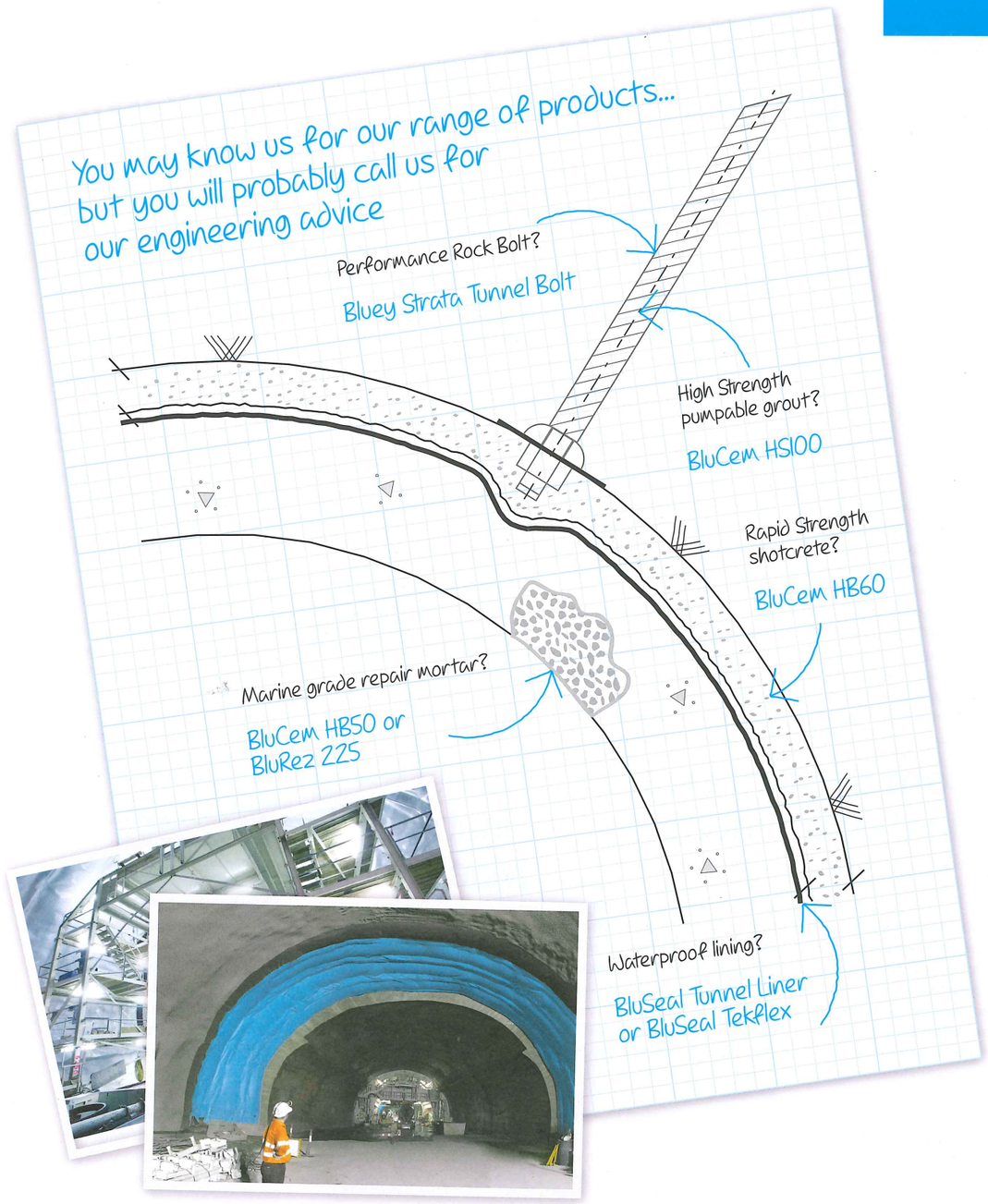
The tunnel will cut the current distance between Chenani and Nashri from a treacherous journey of 30km to a 10km all-weather route and reduce travelling time by up to an hour.

Russell Waugh, managing director of Leighton Welspun said, "we are very pleased to see this nationally important project underway. It is not only a landmark project in the history of India's transportation network but will bring increased safety."

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Poyry expands in Sweden and hydropower

FINLAND

Finnish engineering practice Poyry has completed the purchase of parts of the Vattenfall Power Consultants engineering consulting business, to form a new company, SwedPower.

SwedPower activities, including 245 transferred jobs, are now being included in Poyry's reporting. The business involved generated pro forma net sales of SEK 480M (USD 74.8M) in 2010. SwedPower activities, ranging from advisory services to engineering and project management, are focussed on three sections of hydropower, wind power and power networks including thermal power.

The purchases were originally announced in April, and are seen as opening major opportunities for common projects in the energy sector globally.

In its latest financial figures Poyry reported a 30.3 per cent increase in order stock to EUR 742.1M (USD 1067.6M) over the same period last year, and a 12.2 per cent increase in net sales for the first six months.

However, the report's outlook for 2011 indicated uncertainty on the investment decisions of clients.

It said,"During the summer the uncertainty around the general economic outlook has increased, which may also impact investment activity in business segments that are relevant to Poyry's operations."

New Bilfinger Berger chair appointed

GERMANY

Roland Koch took over as chairman of the German services and construction contractor Bilfinger Berger executive board on 1 July, succeeding Herbert Bodner, who has retired after 12 years as head of the company.

Koch has been on the executive board since 1 March, and was premier of the state of Hesse from 1999 to 2010. He has specialised in business and labour law.

As a civil engineer, Bodner was instrumental in Bilfinger Berger's realignment from a construction company to a multi-service group. The company has recently become more involved in energy, divesting its construction activities and, according to the company, freeing it from dependence on the cyclical demand in construction.



Right: Roland Koch

Aecom appoints water VP in the Americas

USA

Marshall Davert joined Aecom this month as executive vice president, responsible for the water business line in the Americas.

Based in the Dallas office, Davert will oversee the performance, strategic direction and growth of the company's water business in all areas, including water, wastewater, water resources and community infrastructure, in the Americas.

"We are delighted to welcome Marshall," said Rob Andrews, Aecom global managing director, water. "His experience leading mega global water projects will be vitally important as we continue to expand Aecom's Water business line."

Davert has more than 25 years of experience on global water projects, including planning, design, construction, implementation and management. His most recent position was with water consulting and construction services firm MWH, based in Sydney, as president of the company's Asia-Pacific division.



Left: Marshall Davert joins Aecom

Safety double for MacDow

SINGAPORE

McConnell Dowell announced a safety milestone and award last month.

Work on Singapore's Downtown Line Two passed two million man hours without lost time due to injury. A spokesman said this target was particularly significant because "the activities leading up to this milestone were especially complicated and of high risk," including road diversions, piling operations and TBM delivery all within a congested work site.

McConnell Dowell also won the Land Transport Authority's annual safety award on 29 July.

News in brief

Alaskan Way manager goes to CH2M HILL
Ron Paananen, program manager for the Washington State Department of Transportation's (WSDOT) Alaskan Way Viaduct replacement tunnel in Seattle has accepted a job with engineering firm CH2M HILL in Washington, D.C., starting in October. WSDOT's Linea Laird will be taking on the role of program manager and previously served as project manager for the Tacoma Narrows Bridge Project.

Normet acquires Essverk
Normet Group acquired mining and tunnelling equipment and service business Swedish Essverk Berg AB as of 1 September. This includes relevant assets and employees. The acquisition gives Normet a physical presence in Sweden, said Aaro Cantell, chairman of Normet Group.

SAK moves headquarters
Tunnelling contractor SAK Construction relocated its headquarters to a larger, newly renovated facility in O'Fallon, Missouri. Among the functions of the new building will be to provide an interior space for the storage, maintenance and repair of the firm's tunnelling equipment.

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Sandvik divisions swap cities and presidents

SWEDEN

Sandvik rolled out major corporate changes and relocations this month. A new executive management team was appointed effective 1 January 2012. New members on the team will include Tomas Nordahl, executive vice president with responsibility for IT, sourcing and strategy; Gary Hughes, president of Sandvik Mining; Andreas Evertz, president of Sandvik Machining Solutions and Thomas Schulz, president of Sandvik Construction.

Also announced were various office relocations. Sandvik Group will be relocated to Stockholm, Sweden; Sandvik Mining to Amsterdam, The Netherlands, Sandvik Construction to Stockholm with a satellite office in Shanghai, China and Sandvik Venture will be located in Stockholm.

As of 1 October 2011 Ajay Sambrani will be appointed new country manager of India while Svante Lindholm, country manager in China, will retire in the same month. A process to find his successor has begun.

Strabag breaks even

AUSTRIA

Austrian contractor Strabag reached the break-even point in earnings before interest and taxes (EBIT), a feat it has never achieved before the third quarter in past years.

CEO of Strabag, Hans Peter Haselsteiner said, "The first months of the previous year were characterised by a very long winter. This year's weather conditions allowed us to begin building significantly earlier, which is why we are pleased to report a double-digit growth of the output volume at the halfway point.

"We also have good news on the earnings side: last year's EBITs were significantly positively distorted by a one-off effect in the balance sheet. This makes it that much more remarkable that, for the first time in company history, we have registered a positive EBIT already at the half-year mark. We already raised our forecast for the full year 2011 and beyond, during the presentation of the interim report for January-March 2011.

He added, "Today I would like to confirm this outlook. We expect an output volume of USD 19.8bn in 2011 and of USD 20.2bn in 2012. The EBIT should come to rest at least at USD 452.2M this year and at USD 466.3M next year."

ITA Contractual Framework Checklist released

GLOBAL

The International Tunnelling Association has published 'The ITA Contractual Framework Checklist for Subsurface Construction Contracts' drawing from work undertaken by ITA Working Group WG3 on Contractual Practices.

An ITA spokesman said that the document indentifies the key contractual practice areas believed to be fundamental for ensuring the success of subsurface construction projects. Chief executive Olivier Vion said that existing standard forms of construction guidelines and contracts do not adequately deal with the particularities of the subsurface environment.

The spokesman said that application the framework, "Will enhance the possibility of achieving the project objectives for all stakeholders."

Rather than specifying resolutions, which are peculiar to each project, it recommended that timely and appropriate consideration of all the matters raised in the publication is essential for successful subsurface project delivery.

The 12-page document is available from the ITA and via http://en.calameo.com.

Tunnellers will leave for more money

Bosses be warned. In a *T&TI* opinion poll carried out in late July some 85 per cent of tunnellers said they would leave the tunnelling industry for a higher salary.



News in brief

Dubai Metro awareness
The Dubai Roads & Transport Authority (RTA) has launched a campaign to raise public awareness of the metro system prior to the scheduled opening of the Green Line on 9 September. The RTA was keen to make the metro the first and favourite choice of the public. The Salah Uddin underground interchange station with the Red Line is claimed to be the biggest metro station in the world.

Call to tender for A8
Invitation to tender using restricted procedure, for construction, support, sealing and lining of a 760m-long, three-lane single tube tunnel and associated works on A8 autoroute in La Trinite, France. Deadline 7 October. Contract duration 30 months. Contact: vincent2.martin@egis.fr

Zed Tunnel Guidance Wins Queens Award
Zed Tunnel Guidance, based in Walton on Thames, Surrey, UK, was a recipient of the Queen's Award for Enterprise. Zed won a South East Region award in the International Trade category. Zed Tunnel Guidance has specialised in TBM guidance since 1975.

UCA of SME welcomes new executive committee members
Five new members – Judy Cochran, Heather Ivory, Nasri Munfah, Mike Roach and Leonard Worden – joined the executive committee of the Underground Construction Association (UCA) Division of SME during the Rapid Excavation and Tunneling Conference (RETC) in June in San Francisco. The committee also welcomed Jeff Peterson as incoming committee chair and Bill Edgerton as incoming vice chair of the committee.

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To plan or not to plan the use of underground space

For cities all over the world, sustainable development is a key issue. But are they missing out on possibilities and is the proposed development really sustainable? Han Admiraal, chairman of ITACUS, explores with *T&TI*

ITACUS, the ITA Committee on Underground Space, has looked into the question of whether cities are missing out on possible uses of underground space for sustainable development and come up with three white papers dealing with the use of underground space. Their basic finding is that not using underground space as part of developing a city is unsustainable. The second finding is that even when cities are using underground space, not planning the use also leads to non-sustainable development.

Below the surface of cities lies a vast social asset in the form of underground space. Underground space can be thought to consist of four major resources: space, water, geo-materials and geo-energy. Often when looking at the use of underground space, only the space resource is highlighted through examples such as underground mass rapid transport systems; quite rightly, as many of the world's mega-cities use the underground space for underground transport systems and have been doing this since the end of the 19th century. One of the more modern uses of underground space is for geo-energy purposes. In the quest for alternative and renewable sources of energy, geo-energy has proven to be an interesting concept. As these examples illustrate, there is most certainly a case for using underground space and indeed consider using it when talking about the development of cities. Not doing so leaves a valuable societal asset unused, an asset that can contribute greatly to sustainable development. Leaving it to go to waste therefore implies that any development not including use of underground space cannot be sustainable.

The two examples given above also illustrate that as underground space can be modelled to consist of the four mentioned resources, competition for space can arise not only within the context of one of these resources but also between these resources. Cities which have long been at the forefront of developing large scale underground systems like London and Paris, are increasingly becoming aware of the problem of space shortage. There is congestion below the surface causing new systems to be developed at greater depths with all the additional risk and costs this brings. It also means longer travelling times for passengers and more difficult evacuation scenarios in case of emergencies.

But not only do we see congestion in terms of space use from these transport systems. As the use of geo-energy applications is rapidly increasing, so is the chance of a potential conflict between applications in the horizontal plane, e.g. transport systems, and these vertical geo-energy applications. The conflict can be both in terms of hitting an object not charted but, more importantly, the vertical geo-energy applications could prevent future development in a serious way, given the great depth that these systems often reach.

ITACUS is trying to make the case for the necessity to plan the use of underground space by underlining these two potential conflicts. Not planning the use of underground space leads to the current practice of 'first-come, first-served' usage of the underground space. This can lead to serious problems as many Western cities are already aware. It can also seriously hinder future sustainable development of underground space and therefore cities. Not planning the use of underground space is not only a bad policy decision in the short term, it leaves future generations with serious new problems in the long term. And that makes it another prime example of non-sustainable development.

A final reason for considering planning the use of underground space is that it can often lead to surprising new applications hitherto not considered. Kuala Lumpur has been successful in implementing its Storm Water Management and Road Tunnel (SMART). It has proven to be a smart thing to do. The combination of what to all intent and purposes is a large storm water drainage tunnel with a road tunnel leads to an optimal usage of underground space. It combines two policy fields which would normally not be thinking of combining their actions. When cities develop a vision on the use of their underground space and then plan this use, they will find that combinations like the SMART in Kuala Lumpur will be found. Multi-functional use of underground space, combining its resources could very well prove to be the next step in sustainable development of large and mega cities worldwide.

In the film Contact, Jodie Foster plays a scientist searching for alien life. When asked by a small child whether or not she believes there is life out there, she answers: "If not, it seems an awful waste of space." This applies equally to all that space below our cities. Develop a vision, plan the use and then start using it. We can no longer afford not to use it.



Above: Han Admiraal, ITACUS chairman, is a former professor of underground space for the universities of applied science in Utrecht, Tilburg and Vlissingen. He works as an independent consultant in the field of underground space and is based in Rotterdam, Netherlands.



Below: Helsinki, host city of World Tunnel Congress 2011: 'underground spaces in the service of a sustainable society' is the first city to have fully modelled its underground space

About ITACUS

The International Tunnelling Association's Committee on Underground Space (ITACUS) was set up to address the issue of underground space use worldwide and to raise awareness with regards to both the actual use and the need to develop a vision which allows for planning the use of underground space.

ITACUS has been created specifically to bring together professionals from around the world to address the issues that will arise from these needs. The ITACUS website can be found on the ITA site: www.ita-aites.org under 'committees'.



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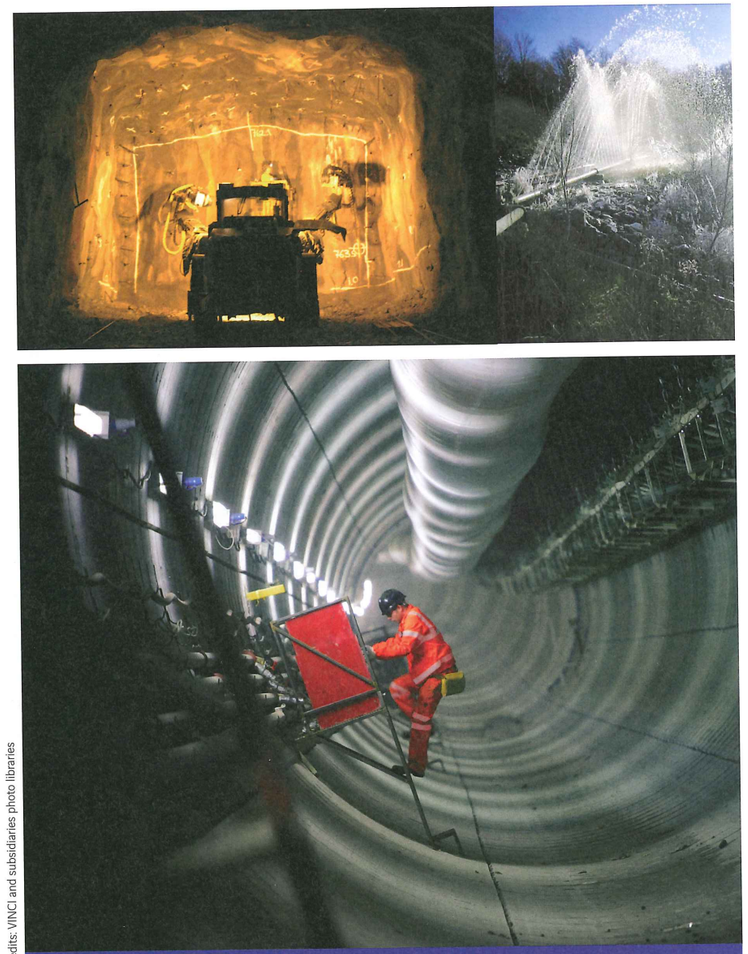
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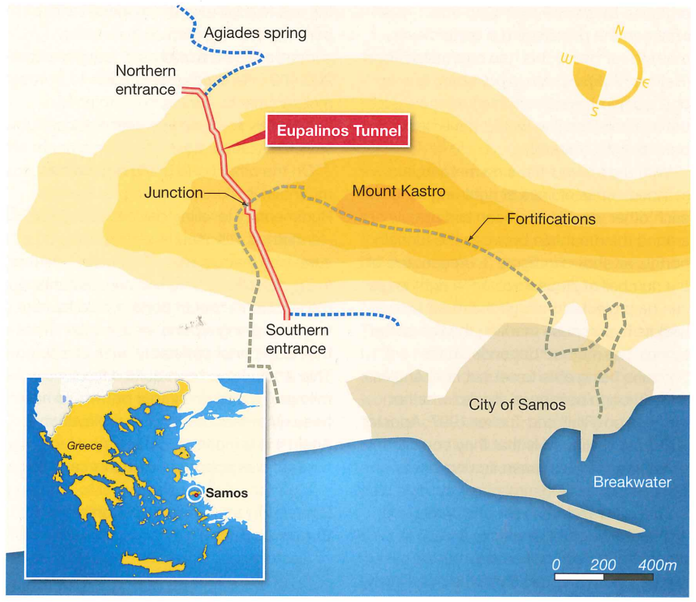
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The Eupalinos' Tunnel on the Island of Samos

A dictator's legacy, brutal working conditions and ancient instrumentation are examined in this report on what was both the longest tunnel ever built at the time and the first to be driven from both ends. Dr Myles O'Reilly, chairman of the *T&TI* Editorial Advisory Board, gives an insight into the techniques, thinking and capabilities of ancient tunnellers



Left: Figure 1, plan of Eupalinos Tunnel

Chance can play a large part in many of our activities and it was a book published a few years ago entitled 'The Man Who Invented History: Travels with Herodotus' by Justin Marozzie that sparked this author's interest in the Eurpalinos' tunnel.

Driven simultaneously from both ends of the alignment by the Greeks in the 6th century BC (Sandstrom 1963) this 1,040m-long tunnel was successfully constructed to provide a reliable water supply to the ancient city of Samos, now called Pythagorio (in memory of Pythagoras, the philosopher and mathematician of hypotenuse fame who was born on that island circa 570 BC).

Background

Samos, a comparatively green and fertile Greek Island, is located in the North Aegean Sea just off the coast of Turkey from which it is separated by the narrow, 1.6km wide Mycale Strait. About 45km long and 13km wide at its greatest extent, it has an area of almost 480km^2 and a population of around 34,000. A large portion of the island is covered with vineyards and apart from grapes the main agricultural products are honey, olives and olive oil, citrus fruit, dried figs, almonds and flowers.

Although the early history of Samos is obscure, it was relatively quick to develop, and by the 6th century BC it had become one of the main commercial centres of Greece largely due to the island's proximity to trade routes. A succession of tyrants culminating in the rule of Polycrates saw the island reaching the height of its prosperity around 535 BC.

Engineering works

These were interesting and exciting times for Samos. There was a growing threat from the Persian Empire at its doorstep on the nearby mainland, while Polycrates with the most formidable fleet in the Aegean had expansionist ambitions. Thus defensive measures were needed on the island to provide a secure basis for conquest and piracy abroad. The Eupalinos' tunnel formed part of these defensive works, which also included city walls at just over 6.4km long, 6m high and 2m wide, with 31 towers, a moat to the west of the city of Samos and a breakwater extending some 400m out into the sea, which was up to 18m deep to provide a harbour sheltered from southerly winds. Contemporaneously the Heraion, the largest temple in the world at that time, was under construction to the west, further along the southern coastal plain. Indeed, this part of Samos must have looked like a building site for much of the 6th century BC.

Writing a century later, Herodotus considered the tunnel, breakwater and temple the three greatest works of the Greeks. He judged the tunnel to be pre-eminent while providing only brief details of the other two works.

The Eupalinos' tunnel

This water supply tunnel which remained in use until late Byzantine times was rediscovered by Abbot Kirillos in 1881 and found to be essentially as Herodotus had described it. As already indicated it is

1,040m long and was driven through Mt. Kastro, a 239m high hill, to convey water from the Agiades spring to the north into the city of Samos. The tunnels consists of two parts:

- An upper section which is generally squarish, 1.8m wide and high with a horizontal floor
- A lower part where open topped gutters have been laid at the bottom of a trench located along the east wall of the tunnel. This trench varies in depth from 3.4m below the tunnel floor at the northern entrance to 8.5m at the southern exit: hence the gradient of the water channel is about one in 200 or 0.5 per cent. See figures 1 and 2.

Herodotus tells us that the architect for the tunnel was Eupalinos, son of Naustropos, who hailed from Megara on the Greek mainland. Unfortunately he does not tell us how Eupalinos determined the alignment and level for the tunnel or how it was constructed. Mt. Kastro is composed of Miocene rocks – soft marls and limestone to the north and hard limestone to the south (Higgins and Higgins 1996). The workmanship was of a high standard. The ceilings and walls are generally bare rock that appears to have been peeled off in layers and chisel marks can still be seen.

The tools for excavating were hammer, chisel, candle or lamp and bucket. The interesting question is the rate of progress achieved. Estimates vary from five to 15 years to complete the tunnel; the meeting point between the two drives is 620m from the northern entrance giving an average daily rate of progress of within the range 0.11 to 0.34m per day on this leg of the tunnel. It has been suggested that the southern leg of the tunnel could have been started some years after the northern leg but there is no mention when positing this that the limestone is harder to the south.

Working conditions were almost certainly poor and work would probably have gone on round the clock seven days a week: given the harshness of the conditions it is very likely that the tunnellers were slaves and it is hard to imagine may of them surviving from start to finish of the project. However one looks at it, this was a colossal achievement for manual labour.

Setting out the tunnel

Equally impressive was the determination of the line and level on which to construct the north and south legs of the tunnel so that they would rendezvous somewhere beneath Mt. Kastro. And there has been much speculation on how Eupalinos solved these problems. The two ussues are ensuring that the two legs were correctly aligned and that the floor of the upper section of the tunnel at the north and south portals was at the same elevation. Both problems can be solved by going either over the top or around the side of the mountain, or indeed by using both methods in conjunction as any first rate engineer – and Eupalinos certainly was that – would do if both were available at the time.

Aligning the tunnel

With the over-the-top method it is relevant to remember that the tunnel was just over a kilometre long so that 100 people along the line would be only 10m or so apart. It would not be too difficult to organise these into a straight line between the portals and a quite clever method for doing this has been described (Belloc 1925). Even a rope, string line or chain could have been used. Once determined, the line would have been permanently marked.

With the around-the-side method, a stepped series of lines at right angles to each other would have been laid out around the mountain between the tunnel portals as shown in figure 3. Irrespective of the number of steps involved, a right angle can be projected through the mountain with its hypotenuse marking the line of the tunnel. The method depends on the Samians being able to set out right angles and although opinion is divided whether this was so (Rihill and Tucker 1997, Apostol 2004) the likelihood is that they could, given that they had been around since Egyptian times.

Take your pick then on what was used but on the basis of simplicity and straightforwardness the over-the-top method would appear to be the more likely.

Once the line of the tunnel had been determined externally, projecting it once the tunnels were inside the mountain is the problem. Again there is no information on how it was done. Indeed it would appear that they made life difficult for themselves since the entrances of both ends have been dug off line and do not follow the direct alignment until some 7m and 15m inside the hill of the north and south ends of the tunnel respectively. How they did it all was certainly clever stuff for those times.

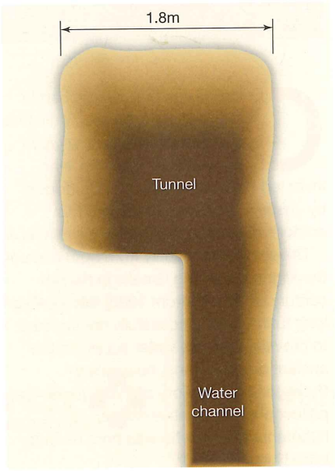
Finding the level

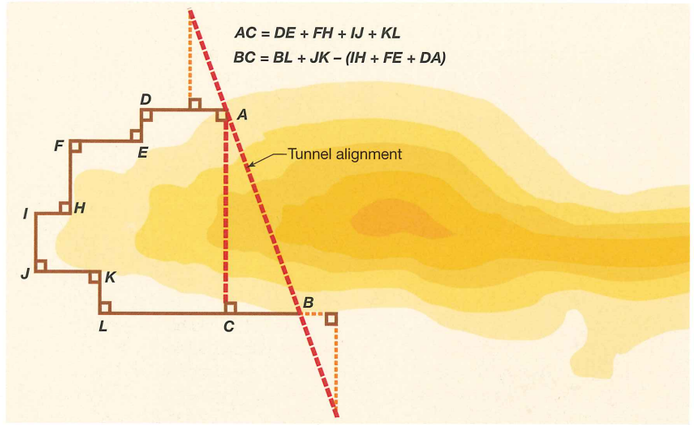
This appears to be the more difficult problem. With the over-the-top method, measuring poles would be used to measure the height up one side of the mountain and down the other. Logically they would have started from the north portal, not necessarily but preferably in a straight line up the mountain, sticking in measuring poles as needed to ensure that they could sight horizontally from the upper part of the lower pole to the bottom part of the one above. On reaching the top they would add up all heights measured on the poles going up the north side of the mountain. The process was then reversed coming down the south side of the mountain until the sum of the heights equaled that for the north side which was the level at which the south portal should be excavated to provide a horizontal floor to the upper section of the tunnel. In principle the method is straightforward and simple but the rise and fall over the mountain with a portal level at the 55m contour and a summit of 239m would have required some 200-400 difference of elevation measurements, each subject to error.

It is likely the outcome would not be sufficiently accurate.

On the other hand going around the mountain is more promising for this task. Rudimentary levelling devices using water – a method still used in setting up surveying instruments – had been invented in Egypt earlier. Using such an instrument, the level at the south portal would be found by going around the mountain from the north portal preferably on the level. This would have been quite difficult following the 55m contour but would have been quite feasible at a lower elevation. Again it is tempting to speculate which method was adopted but in this case it would appear that carrying levels around the mountain would have been easier to accomplish than the alternative.

Below: **Figure 2, cross section of Eupalinos Tunnel**





Above: **Figure 3, around mountain method of finding alignment**

Driving the tunnel

The timescale of construction of the tunnel has already been considered, and had the tunnellers trusted the setting out and continued on the straight-line direction on which they began, a near perfect junction would have eventuated. However there were obviously doubts in their minds and there would have been ample time for them to fester and cause concern. About half way to the meeting point, the northern leg begins to zigzag and changes direction a number of times before finally making a sharpish left turn to intersect the south leg. Floor level in the north leg was 580mm higher than in the south leg, just another of all the remarkable achievements on this project.

Construction of the inclined channel for the water supply would have been another time-consuming operation given that the width of the excavation was just sufficient for a single person to carry out the excavation. Located along the eastern side of the tunnel and up to 8.5m deep, the amount of excavation involved was approximately 3,000m³ and only a little less than from the upper section of the tunnel. Its completion would have been the final act in the construction of the tunnel. Nobody knows how long it took to complete the project and, as already mentioned, estimates range from five to 15 years on the basis that things usually take longer than expected, this author's preference would be for the longer period.

Resourcing

Quite significant amounts of labour and materials were required for the building works in the city of Samos and its environs for much of the 6th century BC. Highly skilled labour was needed for the planning, design and setting-out and supervision of the water supply system, temple, fortification and breakwater. In the case of the water system, the Samians obtained the services of an outsider, Eupalinos of Megara. On the other hand two locals, Thoikos and Theodoros, were responsible for the Heraion temple. It is unlikely too that all the skilled craftsmen and semi-skilled workers could have been obtained within the island of Samos and some would almost certainly have had to come from elsewhere. Indications are that Polycrates paid high wages to immigrant craftsmen.

Working conditions within the tunnel have already been mentioned with most of the workforce likely to have been slaves given Polycrates' penchant for piracy. One can visualise two, perhaps three men working at the face by the light of smoky candles or oil lamps with their noses and mouths protected by cloths from the dust their chiseling is creating. Behind, their helpers are cleaning out and carrying away the excavated rock, removing blunted chisels and supplying re-sharpened or new ones as well as providing food and drink. There was only natural ventilation. Excavation probably continued 24 hours a day and we do not know how many shifts there were. But we can almost certainly be sure that working conditions were awful and nobody had heard of health and safety!

By comparison with other building projects on Samos dealing with the 3,500m³ or so of excavated rock from the upper section of the tunnel at a rate of about 1m³ or two tons per day would not have been difficult. The supply of the 2.5km of clay pipes and guttering at an average rate of about a metre a day would be quite easy.

Conclusion

Engineering world firsts – which the Eupalinos' was in both length and being driven from both ends – are of their very nature remarkable achievements and indicators of the pinnacle of engineering expertise and capability at that particular time. It is an enduring monument to its skilful designers and the indomitable spirit and herculean efforts of the tunnellers who constructed it. It is also the outstanding project of the tyrant Polycrates. Tyrants, dictators and absolute monarchs can be obnoxious individuals, prone to self-aggrandisement and the wish that posterity will think well of them. Some of them see infrastructure as a route to immortality.

It is fascinating for those interested in the history of engineering and other social matters to reflect on the differences and ambiguities that appear in the various descriptions of the same events. But this is only to be expected and the reader is left to draw his own conclusions. Even now it is an everyday occurrence to find each daily newspaper giving its own view of 'events' and at times differing substantially with each other on the 'facts' themselves. And on many matters new information may emerge years after an event.

In the above piece we may appear to criticise Herodotus for not telling us more. But writing a hundred years later with only hearsay and little else to go on, was he as much in the dark concerning the details of the works as we are?

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For display purposes, T&T will produce two A3 pages on each submission for the judging panel.

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The two Herrenknecht Mixed Shield TBMs used on the Beauty World portion of the Downtown Line Two project in Singapore

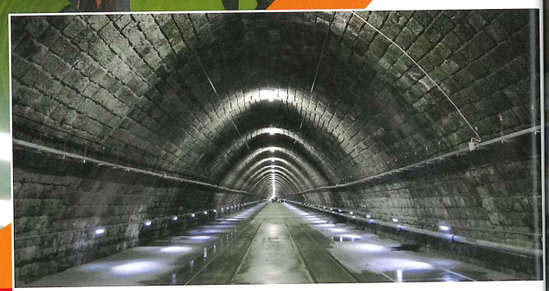




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Dynamism of the East

Running along the fiery Asia Pacific coast are some of the most explosive tunnelling markets in the world. Hong Kong is booming, Japan is storming ahead in innovation, Malaysia is clamping down on corruption and Singapore is a hot bed of activity. Alex Conacher tries to keep up

The Brazilian city of Sao Paulo's win of the World Tunnel Congress (WTC) 2014 is announced on a Wednesday morning. It's 25 May in Helsinki, Finland, and WTC 2011 is already winding up. Exhibitors are ripping down posters, journalists are shaking off the previous night's networking and the defeated WTC lobbyists from Sydney, Australia, and Singapore are nowhere to be found.

It's hard to blame them. They have come a long way to be disappointed by the results of a vote that the victors did not even man a stand to lobby for. There are also whispers around WTC Helsinki that the city's infrastructure is vastly unprepared for the FIFA World Cup in the same year. Still, Singapore had the congress in 2004 and Sydney in 2002 whereas Sao Paulo has not had the honour since 1998. Perhaps an argument for Brisbane would have been more successful (see articles in *T&TI* January 2011, page 16 *T&TI* January, 2011 page 19 and *T&TI* January page 22 for work in and around the city).

But Bangkok in Thailand has the congress next year. This is a good sign for the Asia Pacific market. Usually the line is that, although not able to keep up in terms of the sheer financial muscle available to India and mainland China, Hong Kong (admittedly with central help) in particular, as well as Singapore are a godsend to the industry (see *T&TI* May, page 37). It's often ►

SALE OF TUNNELLING EQUIPMENT

香寶嘉 Dragages HongKong
A member of the Bouygues Construction group

西松建設 Nishimatsu Construction Co., Ltd.

Design and Construction of Hong Kong West Drainage Tunnel
Contract No. DC/2007/10


SCHOMA LOCOS 25T to 27T


SCHOMA LOCO 25T


MAN BASKET CARS 500KG


HIAB CAR 5.6T @ 4.2m


25t LOCOS


11.5m³ Shuttle Car


Hagg Loader 2m³/Min, 8HR2-BH

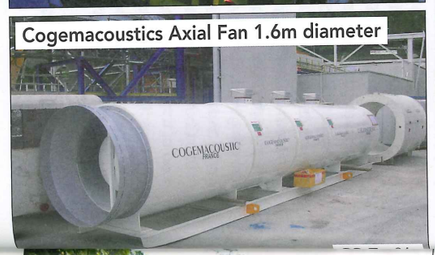

Various Cars
FLAT – SEGEMENT CARS


SCHOMA LOCO 25T


LHD ST2D 1.7m³, Atlas Copco


11 & 12m³ Mixer Cars Muhlhauser


18 Seater Man Cars


Cogemacoustics Axial Fan 1.6m diameter


Various Axial Fans


ULTRANAZZ TUNNEL MIXER 2m³, 1.5m (w)


4m³ Bottom Dump System Skips


0.5m³ with various attachments


Various Excavators

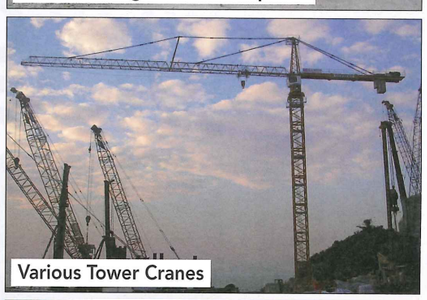

Volvo L70c, 1.8m³

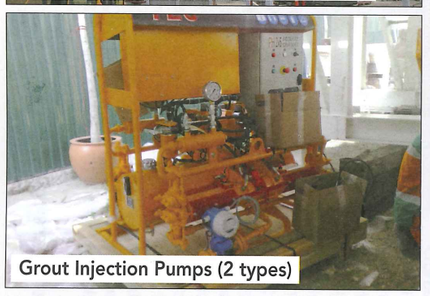

Under Carriage Cars for Skip 6m³

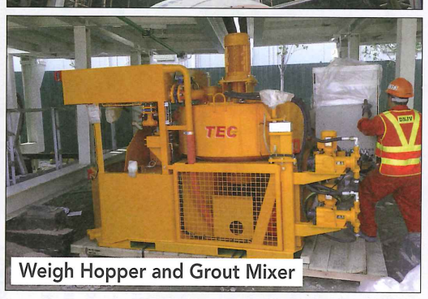

Kone Crane
OH Crane 25t (Height 16m & 30m Span)

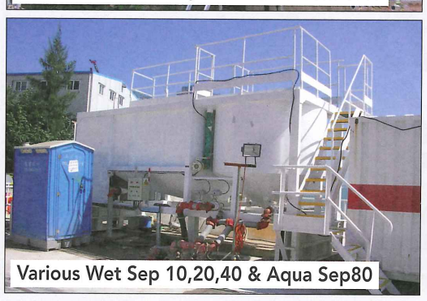

GH OH Crane 5T to 10T, 9m Span
Height: 80 / 100 / 200m


Joinwell Crane Arm, 4.5m-13T / 13m-3.4T


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RELEASE DATE
AUG 2011–MAR 2012

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Shinagawa's shaftless shield

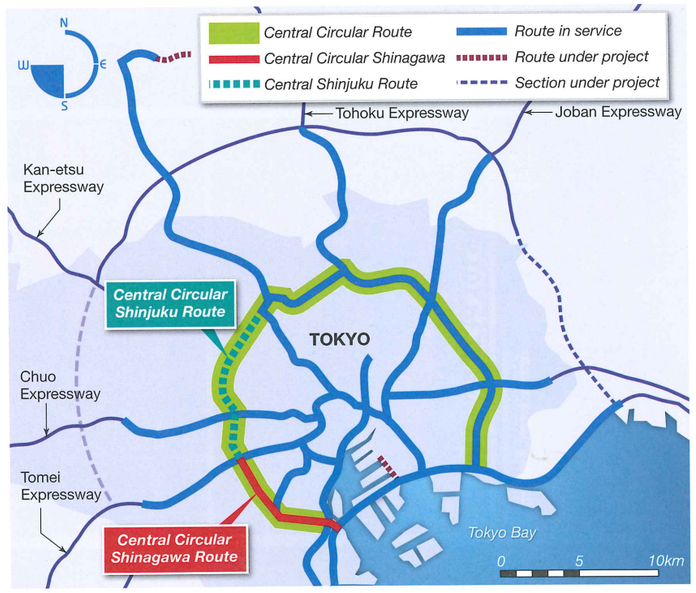
The Shinagawa project is 8km from the dense, metropolitan centre of Tokyo, Japan and must contend with the difficulties inherent in tunnelling under the world's largest megacity. Yasuhito Yokoi, Tsutomu Kimura, Atsushi Kagawa, Satoru Kawauchi and Keizo Miki, all of contractor Obayashi Corporation, present this article on the first use of a surface-launched TBM in Japan

Developed in Japan, the URUP (Ultra Rapid Under Pass) method is being hailed as an epoch-making shield tunnelling technique, enabling rapid construction of underpasses, even in urban centres with high concentrations of roads, utilities and urban infrastructures.

This new technology launches the shield TBM directly from ground level, excavates the tunnel section with shallow overburden and finally arrives back at ground level. This enables elimination of the vertical shafts required for launching and arrival used by the conventional shield tunnelling method, which greatly shortens the construction period.

As a result, the URUP method reduces the impact on the environment by reducing the amount of excavated soil, in turn reducing the number of construction vehicles needed and decreasing carbon dioxide emissions.

The URUP method was first applied in Japan on the Central Circular Route - Shinagawa Line tunnel construction project in the Oi area of Tokyo, Japan, and arrived successfully back at ground level in May 2011.



Above: Figure 1, The Shinagawa project is part of Toyko's Central Circular Expressway that runs on an 8km radius round the city

Project overview

The Central Circular Route of the Metropolitan Expressway is a circular road located at a radius of approximately 8km from the center of Tokyo with a total length of 47km. The Shinagawa Line forms the southern portion of this Central Circular Route, and consists mainly of a 9.4km-long tunnel structure that connects the Bay Shore Line and the Route Three Shibuya Line. Construction is currently underway in order to address the social need to reduce the chronic traffic congestion in the centre of Tokyo. The Central Circular Route is being executed as a joint venture between the Tokyo Metropolitan Government and the Metropolitan Expressway Company, and aims for completion in 2013. Of the various sections, the Central Circular Route – Shinagawa Line Oi area tunnel is a construction project commissioned by the Tokyo Metropolitan Government.

Adoption of the URUP method

The construction area contains important structures such as large drainage canals and electrical power cable tunnels. In the initial planning stage it is assumed that the conventional cut and cover tunnel method will be used, and there are serious concerns about adverse impacts to these important structures due to ground deformation as a result of large-scale excavation work in the soft ground. To address these concerns, the project is commissioned as a design-build contract using a technical proposal-type comprehensive evaluation bid system.

The URUP method receives high marks and is adopted for the following reasons:

- Construction of the vast majority of the route by shield tunnelling minimises the cut and cover tunnel section, which minimises the impact on nearby structures and infrastructure;
- Continuous execution by a single TBM shortens the construction period;
- The amount of excavated soil can be vastly reduced compared to the cut and cover tunnelling method;
- Points two and three minimise the environmental impact by vastly reducing carbon dioxide emissions.

Launching and receiving at ground level

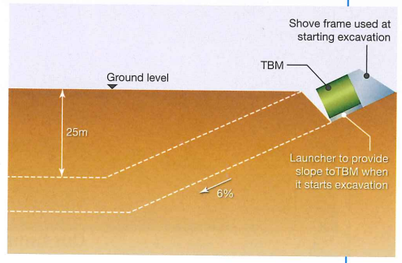
This construction project uses a large-section TBM with a shield outer diameter of 13.6m to construct a two-lane road tunnel. There are many technical issues using this type of large-section TBM in soft ground, as is found in coastal regions, when launching and arriving at ground level with minimal overburden.

However, the shield tunnelling technology developed by contractor Obayashi for Japan's soft alluvial ground that contains much groundwater is able to overcome these issues.

The Ohashi-bound tunnel was constructed first, and marked the first launch of a TBM at ground level in Japan. The TBM arrived at the Oi-kita Ventilation Station after an excavation period of six months, without significant impact on the surrounding ground. The TBM was then rotated, lifted up, and re-launched from the Oi-kita Ventilation Station to construct the Oi-bound tunnel, arriving successfully back at ground level in approximately three months.



Above: The dramatic arrival of the URUP TBM at surface-level reception area in May this year. Photo by H. Nishiyama
Right: Figure 2, from launch the TBM descends at a six per cent gradient, reaching a maximum 25m depth



Manufacturer notes

The machine was manufactured with several innovative features, a spokesman for Hitachi Zosen elaborates:

"The TBM launched from the surface. It could not obtain earth covering during its initial excavation and it was not pressured by earth from its head. Lateral earth pressure would bend the segmental rings into an oval-shape. In order to avoid this, the ring support of TBM retains the segment ring not only vertically but also laterally with a roller."

The spokesman adds, "We mounted all of the equipment on the deck that is usually mounted on back up cars. As a result, the TBM did not have any back up car with it and did not need to rearrange back up car from surface to the bottom of the pit. It helped shorten the construction period of tunnel and enabled the launching pit to be smaller.

"The TBM has fewer spokes compared to similar sized TBMs and had some additive outlet ports on the back side of the cutter spoke to let the additive flow into the chamber. Fewer spokes and less additive into the chamber prevent clogging material from forming in the centre of the chamber, and make management of earth pressure in the chamber easier.

The spokesman finishes, "The centre of gravity of the TBM was positioned almost in the centre of the TBM itself. This made attitude control of the TBM much easier."

Conclusion

The URUP method developed for rapid construction of underpasses is judged capable of solving the various issues facing this tunnel construction project, and realised the first successful ground level launching and arrival in Japan.

Since receiving the order for this construction project, the URUP method has also been selected for three other construction projects in Japan, and construction is currently underway.

It is hoped that in future, the TBM ground level launching and arrival URUP method will be used not only in Japan, but also around the world.

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An innovative approach to landslide prevention



The construction of two drainage tunnels and the associated sub-vertical drain system at the Po Shan area in Hong Kong was completed late last year. This project is the first of its kind to utilise drainage tunnels and a network of sub-vertical drains to regulate the groundwater table to enhance the long-term stability of hillsides. The success of the project offers a feasible and effective solution for future landslide prevention and risk mitigation on steep and hilly terrain, a topography found in many parts of Hong Kong. Aecom senior engineer Dr Johnny Cheuk authors this paper on the work

Hong Kong's high population density and mountainous terrain have resulted in a number of notable landslides over the decades. One of the most tragic events occurred in 1972 when a catastrophic landslide on the hillside of the Po Shan area took the lives of 67 people.

This unforgettable collapse, along with other major landslide events, formed the historical background for the slope safety efforts undertaken by the Hong Kong Special Administrative Region (SAR) Government. Detailed investigations and research studies were carried out and the results indicated that the natural hillside of the Po Shan area was affected by high groundwater levels and unfavourable geology. Subsurface drainage measures, in the form of horizontal drains, were put in place but, after some 20 years, the monitoring data showed signs that the groundwater levels in the drained area could be high during heavy rainfall. It was in this context that Aecom was appointed by the Civil Engineering and Development Department (CEDD) of the Hong Kong SAR Government to design a robust landslide preventive system to protect Po Shan residents from large-scale deep-seated failures. With this in mind, an innovative scheme involving a pair of drainage tunnels and over a hundred sub-vertical drains was adopted for the project.

Project description

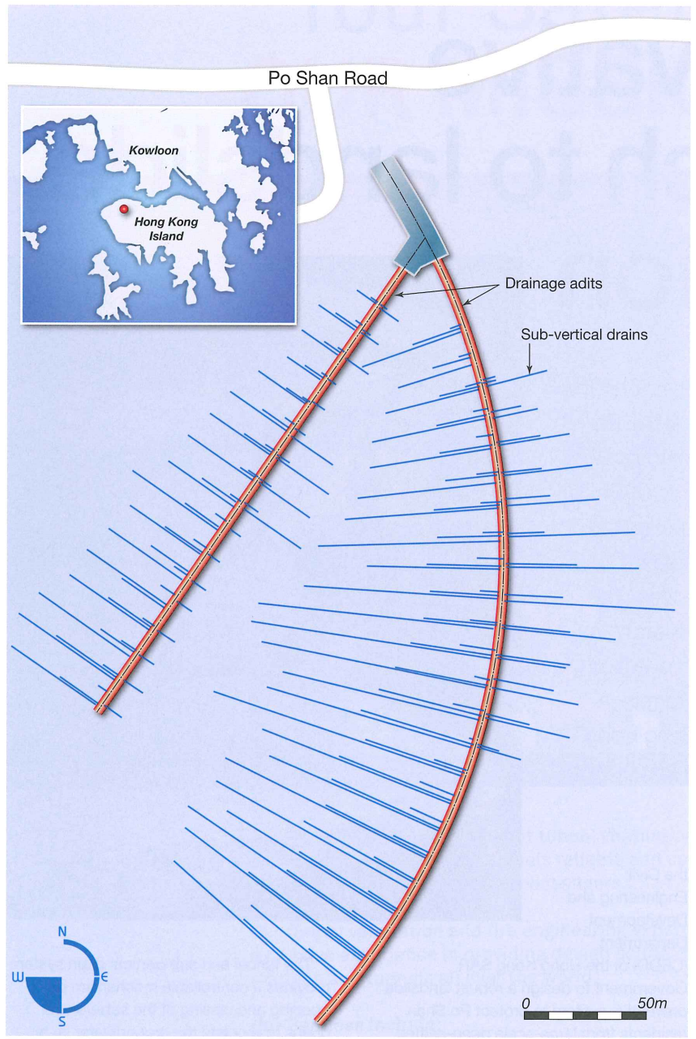
The project consists of two 3m-i.d. TBM tunnels. The high tunnel cuts 310m into the face and has an overburden of 140m at its deepest point. The low tunnel cuts 219m to a depth of 80m. Some 172 sub-vertical drains were installed from inside the tunnels and extended into the soil. The drains were designed to cover the area of the entire drainage zone of the catchment, which falls largely within the Pok Fu Lam Country Park and is mainly covered by dense vegetation.

The tunnel and sub-vertical drain system provides a controllable mechanism by opening and closing of the sub-vertical drains to regulate the groundwater level and ensure that variations in groundwater levels fall within pre-defined ranges.

While the initial set-up cost for the sub-vertical drains was higher than horizontal drains, it is more practical, cost-effective and sustainable when it comes to future operation and maintenance. Also, from an environmental standpoint, the sub-vertical drains were designed to be installed inside the tunnel and did not involve any ground surface works. This means that no tree felling was required and no vegetation was adversely affected by this project.

As part of the Landslip Preventive Measures Programme managed by the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development





Left: Figure 1, plan of tunnels and subvertical drains under Po Shan hillside

Department, the entire project was designed by Aecom and constructed by the China State-China Railway joint venture. Construction commenced in July 2006 and was completed in December 2010. The performance of the drainage system is being closely monitored for a period of two years in order to verify the effectiveness of its drainage capability and to identify the most effective operational procedures going forward.

Successful completion of the project was not without technical challenges, some of which had to be resolved by novel engineering solutions. Specifically, a number of innovative techniques and value-added features were adopted for this project, such as the use of Horizontal Directional Coring (HDC) for ground investigation, upward drilling from a confined space, a retractable TBM, and an automated wireless groundwater monitoring system in addition to collaboration with the Hong Kong Observatory to monitor seismic activities.

HDC for ground investigation

Tunnelling is traditionally acknowledged to be a high-risk construction activity as ground conditions can be challenging and difficult to predict. HDC can provide a continuous assessment and sampling of the ground conditions along the exact tunnel alignment, which is analogous to a pilot tunnel. As a result, unforeseen tunnelling conditions can be largely avoided. The continuous geological information is also valuable to assess the construction programme, grouting works and excavation methods, such as the use of TBM and/or drill-and-blast. Areas of problematic rock conditions can be located using HDC, and a specific excavation scheme can be proposed before tunnelling starts. HDC also enables the measurement of groundwater inflow in different tunnel sections: it is valuable data for the grouting design as it directly impacts the programme and cost estimation of tunnel construction.

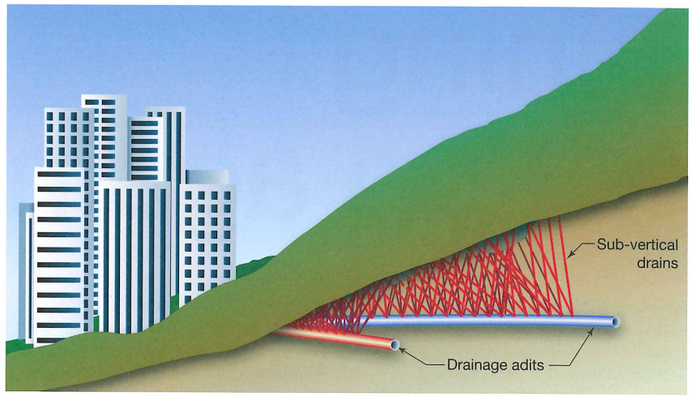
Retractable TBM

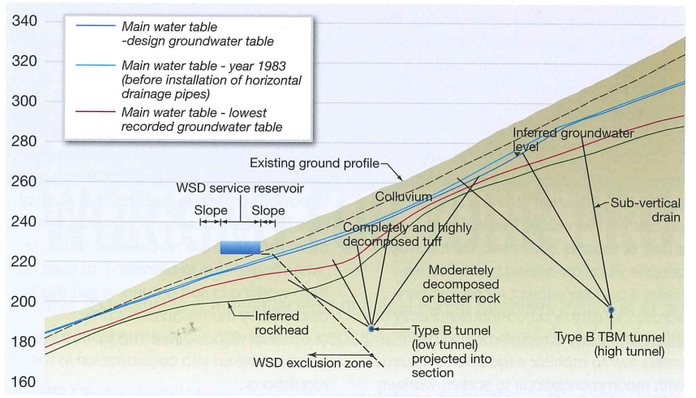
Although tunnelling by TBM has been commonly used in Hong Kong, the operation is usually carried out with both launching and receiving shafts. However, due to site constraints, no receiving shaft was available for this project. This meant that the TBM had to be retracted after completion of the first tunnel and re-oriented to drive the second bore. This 'blind boring' technique, an approach that is rarely utilised in tunnelling, was successfully adopted for this project. Another advantage is the fact that adverse effects on the environmentally-sensitive Pok Fu Lam Country Park, a 270-hectare sylvan sanctuary, were significantly minimised with this method.

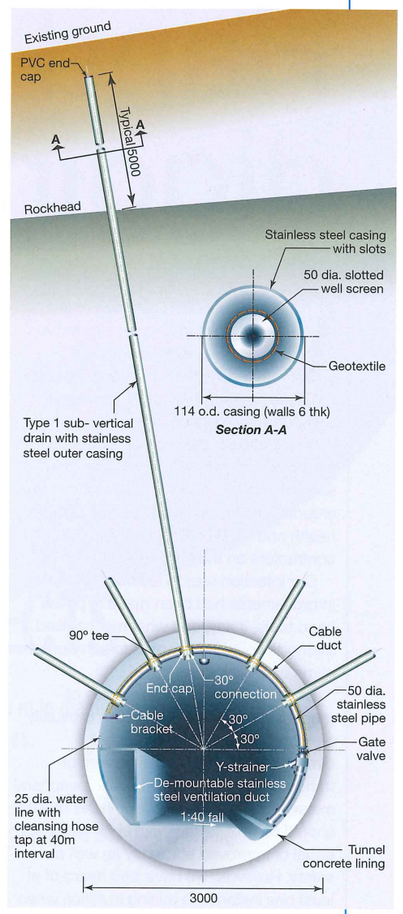
Wireless groundwater monitoring

An innovative Automatic Groundwater Monitoring System (AGMS) was established for the real-time remote monitoring of groundwater data, with the graphical output of monitoring results viewable on a secured website. Using approximately 50 sensors, this state-of-the art system uses wireless networking and the internet to deliver groundwater information directly to stakeholders in real time, without human involvement in the entire process. It currently provides groundwater pressure data for design review and serves as useful reference for future tunnelling projects, all at a very low cost. The use of advanced data acquisition, computing and communications technologies for this project has opened up new possibilities for real-time monitoring on slopes and construction sites. What's more, the use of these techniques is not limited to groundwater monitoring and could also be used for other geotechnical applications.









Top: Figure 2, cutaway three dimensional view of tunnels and fanned drains in the Po Shan project; Above: Figure 3, longitudinal section through drainage system and water table; Right: Figure 4, cross sections showing details of sub-vertical drains

Upward drilling

Sub-vertical drain drilling and installation is a special feature of this project. It is the first project in the world for long-drain drilling and installation, with a length of over 100m, which uses an "up-the-hole" hammer within a small and congested tunnel. As the first application of upward percussive drilling for tunnelling in Hong Kong, it provides an average penetration rate of over 60m per day.

A water hammer, instead of an air hammer, was used during drilling to reduce the chance of jamming. In addition, valves were installed on all drains to control the inflow of groundwater from the sub-vertical drains. While a number of difficulties were encountered during the drilling process such as deformation of casing joints, and jamming of the drill bit, these problems were finally overcome, and smooth drilling and installation ensued.

Hong Kong Observatory

The project is also notable for its deep penetration into bedrock providing an environment with stable pressure, temperature and humidity, which is also shielded from heavy traffic. The access to bedrock and to a low-noise environment makes the tunnel an ideal site for setting up a seismograph station.

The Hong Kong Observatory (the Government department responsible for monitoring earthquakes and tsunamis), GEO and Aecom collaboratively incorporated special features in the project that led to the establishment of the first broadband seismograph station in Hong Kong, meeting the stringent requirements of the Global Seismographic Network for global earthquake monitoring. In the deep rock the station is capable of detecting earthquakes thousands of kilometres away. The waveform data recorded is disseminated through the Incorporated Research Institutions of Seismology (IRIS) real-time, enabling earthquake and tsunami monitoring centres worldwide to determine the parameters of earthquakes in the vicinity of South China Sea quicker and more accurately than with existing systems.

Conclusion

Although it can be a challenge to utilise advanced techniques that have never before been applied, designers should be innovative and strive, as much as possible, to demonstrate the practicality and effectiveness of some of the more innovative methods. With full client support, contractor co-operation, quality supervision of the resident team and acceptance from the general public, implementation of these innovations in this challenging project was successfully achieved.

Hand mining: digging it up again

When *T&TI* selected 'hand mining and the alternatives' as a subject worthy of examining, we were aware of the issue of HAVS (Hand-Air Vibration Syndrome) associated with powered hand mining tools, but were perhaps unprepared for the fact that many attitudes on the subject were still firmly routed in the battles around the turn of the millennium between health and safety officials on one side and contractors on the other.

Our intention was to examine what improvements had been made in power hand tools, if any, and what mechanised methods could be adopted to carry out the same or similar work.

Bearing in mind the economics of modern tunnelling, hand mining is usually restricted to excavations of small dimensions, or to the enlargement of transport tunnels by small-scale, peripheral excavation. Any alternative to hand mining should be able to carry out such tasks with equal or improved efficiency as well as safety. However, we have also heard of at least one instance in mining in Africa when a drill jumbo used for a major development tunnel was dropped in favour of multiple air-leg compressed air drilling on the grounds that it was cheaper and gave fewer maintenance problems.



Due mainly to the location of work, HAVS is not the only heath and safety issue associated with hand mining; others include ventilation, working close to mobile machinery, heavy handling and noise, the last often being associated with vibration. Even mechanised tunnelling can have issues with whole body vibration through inadequate seating and other working positions.

Examination of the subject has revealed several anomalies in opinions including, surprisingly, whether HAVS is actually a problem in tunnelling. This is not helped by a lack of records specific to the industry, despite vibration-related health issues being a popular subject for researchers across industry and non-industrial activities. Also it is usually a requirement in health and safety law to monitor exposure to hazards, with recommendations to screen workers before, during and after exposure in much the same procedure as used for compressed-air working.

However the fact that HAVS is a hazard, i.e. a potential danger, is not generally in dispute, with evidence of long-term or intensive exposure causing damage to the hand and arm circulation and joints. This assertion is based on wide industrial use of powered hand tools, most having different vibration levels and modes of use. Most of the 'horror' pictures first displayed when HAVS became a concern in tunnelling are understood to be related to shipbuilding and boiler-making riveting. On the other hand there have been compensation cases proven on HAVS issues in related activities such as road-breaking and coal-mining. Some other industrial tools that could be hazardous, such as grinders, are also occasionally used in tunnelling.

Even those contractors forward-thinking enough to try alternative, mechanised means of small-scale excavation report difficulties in persuading miners to try alternatives to the power-tools with which they are familiar, such as the CP FL22 and Hauscherr 'German jigger'. Some of this attitude stems from inadequate information on the different mode of operation of the latest equipment, but also, presumably, to 'being happy in their work'.

Contractors also claim that the intermittent use of power hand-tools in tunnelling makes the industry some sort of special case. However, in the past there have been cases of virtually continuous use of power hand-tools, especially in manual pipe jacking. This allows contractors to also claim that there are no cases of HAVS, or 'white finger' due to tunnelling, at least not from working in soft ground. Again this is disputed by the health and safety authorities who say that intermittent use has been taken into consideration in the regulations.

Donald Lamont, former HM principal specialist inspector at the UK Health & Safety Executive comments, "I understand how this thinking comes about as the use of vibrating tools in tunnelling is now on an intermittent basis, however the limits are set out in the Control of Vibration at Work Regulations 2005. Further dose/response studies funded by the tunnelling industry would not be cost effective."

Hopefully the series of articles in this review will throw some further light on the subject because, despite the great efforts of co-operation between various bodies in the tunnelling industry in producing guidelines, there are still great differences in actual practice and attitudes, and what is written down on paper.

Clearly there is still work to be done, in more ways than one, presumably there is money in it; so is it worth it? Give *T&TI* your opinions and experiences, and how you think the industry should reach a position on the subject that all are content with. Write a letter or email the editor on: editor@tunnelsandtunnelling.com.

Left: Raynaud's Phenomenon, or 'White Finger' is the most recognisable symptom in HAVS patients

Maurice Jones with Alex Conacher



HAVS: the nature and reality of the problem

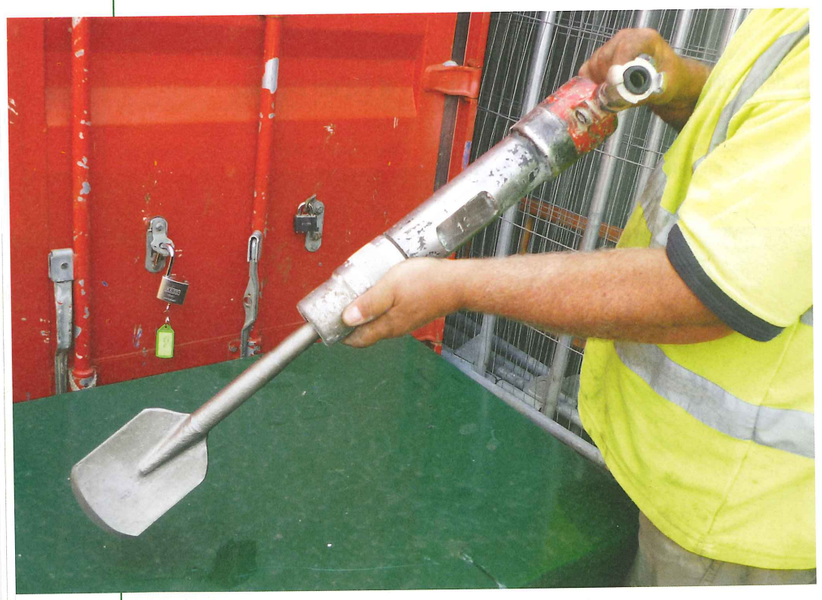
Stances and attitudes to the perceived hazards of hand mining vary greatly throughout the tunnelling industry. Although, as in much of tunnelling, there are many possible dangers such as inadequate support, trips and falls, none has caused as much controversy as hard-arm vibration syndrome, or HAVS for short. Alex Conacher interviewed some of those involved to check on current opinion

Hand-arm Vibration Syndrome is a serious, debilitating condition that without question can ruin lives. Members of the *T&TI* team have relatives affected by the disease. The question of to what extent legislation is applicable to the tunnelling industry, however, and how it should be enforced, is a matter of some debate within the industry as a whole.

Legislation in the UK and some others countries is set out on page 39, but what is important, it seems, is how the law is interpreted and applied in the tunnelling industry. Previous controversy has died down with the drawing up and publication of guidance produced by the combined efforts of industry bodies (such as the British Tunnelling Society (BTS) and Pipe Jacking Association (PJA)) and the UK Health & Safety Executive within the provisions of the European Union Machinery Directive (2002/44/EC – L177, 6.7.2002) but is it sometimes a case of 'carry on regardless'?

Guidance

Practical guidance drawn up by the industry and researchers does not have the direct force of legislation but is often the basis on which decisions are made with regards to whether a practice is acceptable, and so whether enforcement should be carried out.



British and international Standard ISO 5349 (-1 and -2):2001, was actually published two years before the European Machinery Directive. The full title of this Standard is 'Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration, general requirements and practical guidance for measurement at the workplace'. It emphasises that, "Continued, habitual use of many vibrating power tools has been found to be connected with various patterns of diseases affecting the blood vessels, nerves, bones, joints, muscles or connective tissues of the hand and forearm."

Following this, the BTS published 'The Management of Hand-arm Vibration in Tunnelling, Guide to Good Practice' in 2006. L140 'Guidance on Vibration Regulations' is the UK Health & Safety Executive's (HSE's) interpretation of the regulations and is intended by the BTS to be read alongside its own 2006 guidance.

There are several others relevant including the PJA's 'Guidance on the design of hand excavated pipejacks' that was also published in 2006 and includes guidance drawn up in conjunction with the HSE and BTS including small-dimension conventional tunnelling.

In short, there is a lot of tunnelling-specific guidance on the subject. The HSE position on vibration guidance is due for an internal review according to Paul Brereton, HSE specialist noise and vibration engineer. It is the subject of his presentation at the 46th Annual UK Conference on Human esponse to Vibration, at the Health & Safety Laboratory (HSL), Harpur Hill, Buxton on 20-22 September. The L140 guidance document is the HSE interpretation of the regulations legal instrument.

"Things are fairly stable and I can't see that changing," Brereton says. "Guidance change won't be happening, what is likely to change is what suppliers do, the information they provide with their equipment. The machinery directive of 2008 will be involved."

New perspective

Some tunnellers believe a fresh, objective look at tunnelling-specific HAVS guidance and regulation needs to be carried out.

"Tunnelling is not the same as other industries," says Andrew Smith, contracts manager at Joseph Gallagher. "Which is not to say vibration isn't a risk, of course it is, but the guidelines don't take into account that we might be working for concentrated periods with hand tools, and then spend a long time without vibration exposure."

"In some situations it is impossible to avoid hand tools, and in the bigger, high-profile jobs HAVS care is addressed by the client and main contractor more. Timers can be used, and occupational nurses can monitor the situation. The legislation needs to differentiate between constant and intermittent use. No one in the industry knows a tunneller with white finger."

Donald Lamont, former HSE principal specialist inspector of health and safety, civil engineering, says, "I understand how this thinking [that intermittent use is not covered by the regulations] comes about, as the use of vibrating tools in tunnelling is now on an intermittent basis, however the limits are set out in the Control of Vibration at Work Regulations 2005. Further dose/response studies funded by the tunnelling industry would not be cost effective."

Bigger picture?

Colin Mackenzie, the well-respected former tunnelling director of leading contractors and independent consultant, recalls working on the CERN venture at the turn of the millennium, "The bulk of the staff there were from Spie Batignolles (French contractor) and the status of engineers even exceeded that of doctors. I was told that all over Europe, they look at the legislation and decide which bits are relevant before implementing them."

"Sometimes HSE advice can be very helpful. While working on the Jubilee Line, Westminster to Waterloo with Balfour Beatty with a large labour force, two HSE PhDs helped us with instrumental procedure changes that resulted in 1.25 million man-hours without an incident."

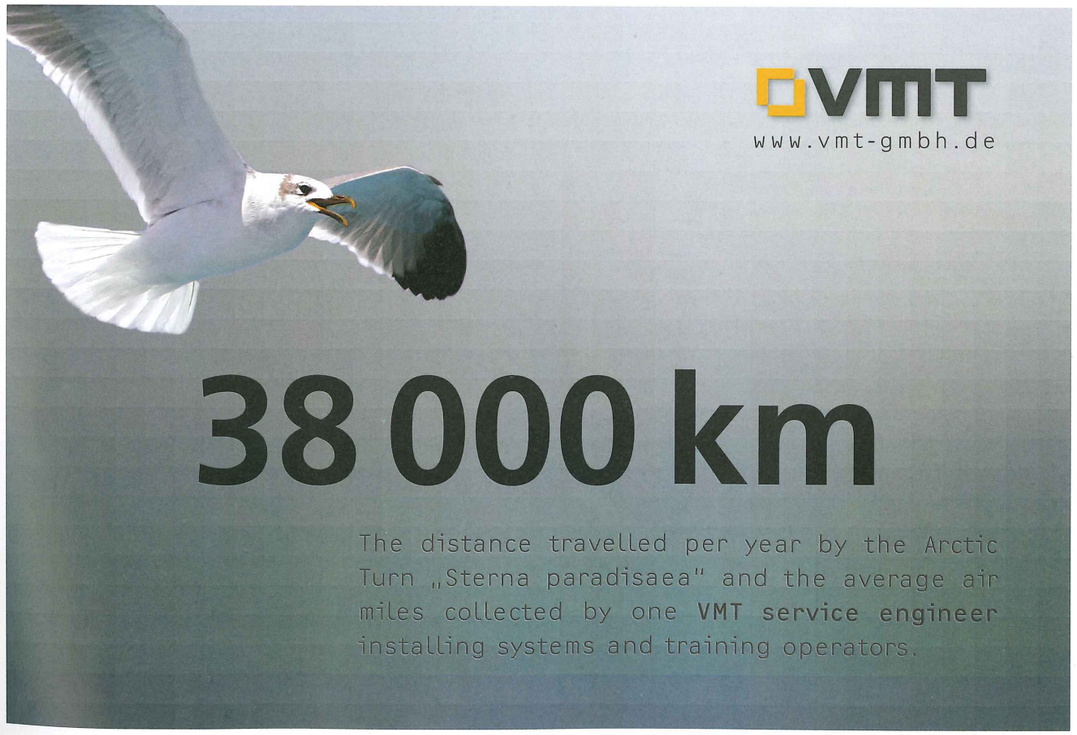
"During the research into how to reduce accidents we found that 90 per cent of all incidents fall into three categories. Falls of objects, trips and falling from a higher level accounted for 50 per cent of accidents; lifting inappropriately accounted for 20 per cent and encounters with plant a further 20. It seems that a large amount of focus has been given to what is, statistically, a minor, side issue.

However, Lamont argues, "Cases of HAVS are known in tunnelling. There is a perception that safety risks e.g. collapses, are more important but the numbers of people suffering from ill health is considered significant."

Mitigation and improvement

"A perceived problem," says Smith, "is that low-vibration machines are often just not very good. When operating tools with cushioned handles, the worker will feel the need to push harder just to get the same results, causing the same issue. It is perhaps better to focus your energy on planning work not to use high-risk methods, and when it is unavoidable to

Left: A typical compressed-air 'spader' for digging clay held in normal fashion





Right: A CP FL22 spader showing top handle trigger

proceed carefully and rotate employees."

Brereton says, "We don't advocate gloves, for example, as a protective measure. Their effect is hard to prove and we advise people to assume zero effect, beyond keeping the hands warm. [On anti-vibration technology] I accept that in the early 90s, some kit may not have been as efficient as the unreduced equivalents, but I am not aware of the same issue in equipment from the late 90s and early 00s onwards."

"When suspension is designed into tools, some pieces of kit are dependant on an appropriate push force, and so training is required. Some people, especially those who are familiar with older equipment think they need to really feel the vibration coming into their hands to get productivity."

He adds, "Our position is that you must let the tool do the work and that if you check productivity, you will find that the manufacturer specs work. There is no need to 'push it 'til your teeth rattle'!"

"A lot of people are working hard to improve low vibration equipment. It's an ever-changing playing field so it would be unfair just to name one or two. I've heard about a bone hammer prototype that is claimed to be less than 2.5m/s^2."

Mackenzie says that although you never see a soft ground man with white finger, ergonomic design of power tools is essential. A good way to protect the fingers, he suggests, is the use of kit with top triggers, operated by the palm, rather than a trigger under the handle that must be finger-operated (see photo of CP FL22 clay spade, above).

"Although London Clay is usually no issue, Boulder Clay in the north of the country is harder, and sometimes when shaping the top of the tunnel with a hand tool at head height, you have to push quite hard and it just doesn't feel right."

Conclusions

"In tunnelling people are traditionally highly exposed," says Brereton. "Old clay spade gangs were a very high risk, using their hands a lot. The advent of TBM and other mechanised tunnelling techniques has enabled a greater management of risk.

"I can't comment on the mentioned absence of white finger, but the risk is of course increased with increased use of hand tools."

Bob Ibell, chairman of the BTS concludes, "The only comment I would make on the HAVs debate is that I believe we do not know enough about it. I believe we need more data so that we can better analyse the problem and its causes.

"We also need to research how we can better identify susceptibility and management and we need to find alternative tools to use to excavate tunnels. It is important that we retain the capability and the skills for all methods of tunnel excavation and support in the armoury."

Additional material by Maurice Jones

Daily exposure

For those unfamiliar with HAVS requirements, the main thinking in measurement and mitigation of the effects of hand-transmitted vibration revolves around the Exposure Action Value (EAV) and Exposure Limit Value (ELV). These are two classification values of exposure to acceleration due to vibration, normalised over an eight-hour period (a working shift). The EAV, the level at which employers are required to take immediate action to control further exposure is 2.5m/s^2 A(8). The ELV, the maximum amount of vibration an employee may be exposed to on any single day, is set at 5m/s^2 A(8). Daily exposure can be calculated as follows:

$$A(8) = a^* hv \sqrt{\frac{T}{To}}$$

Where alpha*hv is vibration total value of frequency-weighted root-mean-square (RMS) acceleration, the root-sum-of-squares of the RMS single-axis acceleration value of the frequency-weighted vibration, which gets you values for triaxial vibration in m/s^2 (EAV and ELV require three axes of vibration to be considered since a 2001 revision).

Where T is the total daily duration of vibration exposure.

Where T0 is the reference duration of eight hours.

The ISO 5349-1:2001 continues, "The vibration exposures required to cause these disorders are not known precisely, neither with respect to vibration magnitude and frequency spectrum, nor with respect to daily and cumulative exposure duration. The guidance in this part of ISO 5349 is derived from limited quantitative data available. […] However, the use of the information given in this part of ISO 5349 should protect the majority of workers."

Brereton adds, "EAV concerns are relevant to tunnelling to some extent, if you use high vibration hand tools then you know there is a large risk, you can minimise it by avoiding unnecessarily high-vibration tools."

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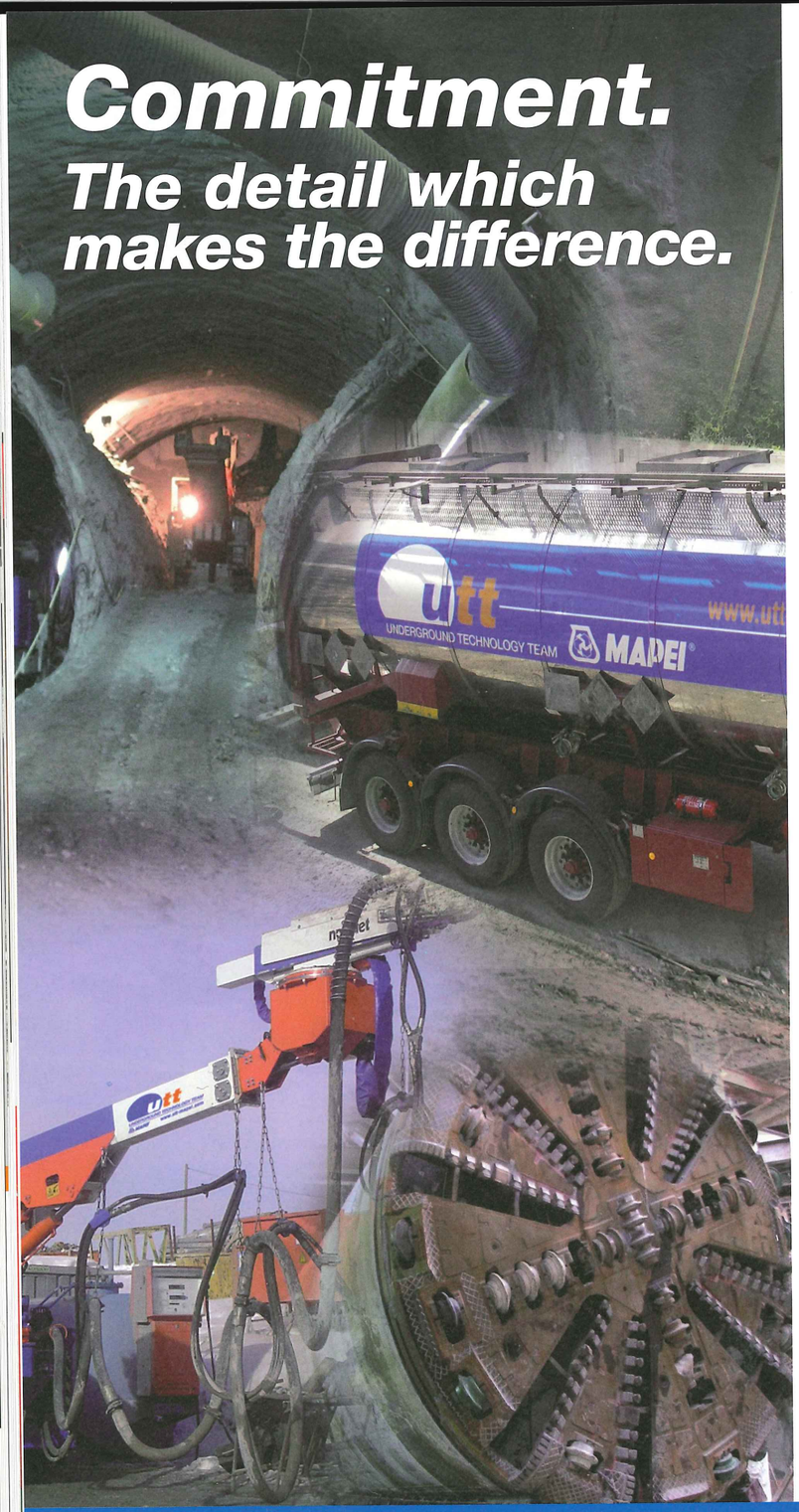
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HAVS in the law

Whatever the arguments and attitudes about applicability, the legislative framework intended to protect the health of the tunnelling workforce, and those encountering vibration in many other industries is inescapable. The editorial team checked on current legislation in some main tunnelling locations

Asking about HAVS law, you are likely to be guided towards the UKs The Control of Vibration at Work Regulations of 2005, which implements a European Council Directive 2002/44/EC (L177, 6.7.2002). This, comparatively recent instrument was preceded only by guidance and standards on the maximum exposure to which workers can be safely exposed.

Europe/International

European Directives take the form of European law under which the members of the European Union (EU) are obliged to comply with and enforce the provisions contained once it comes into force. This may take the form of minimum national legislation to comply with the Directive, but may also include extra or more stringent provisions so long as these do not, unnecessarily, interfere with free trade.

European Council Directive 2002/44/C (L177, 6.7.2002) (known as the Physical Agents Directive) introduced EU-wide provisions for the protection of workers from the harmful effects of vibration caused by equipment and machinery. The European Machinery Directive 2002/44/EC also has relevance.

Like much legislation, it is based on agreed national and international standards in its details; in this case the provisions of ISO 5349 (-1 and -2):2001, Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration, general requirements and practical guidance for measurement at the workplace, in two parts. The equivalent European Standard was approved by CEN in 2001. In addition there is ISO 8041 on human responses to vibration, which has information on measuring and checking the conformity of equipment.

In addition to the EU many others countries have based their safety legislation on the provision of European Directives both in order to establish a framework quickly and also to facilitate equipment exports to the EU.

In Germany the equivalent to the UKs Health & Safety Executive (HSE) is the Berufsgenossenschaft Bau (occupational insurance company).

UK

In general, health and safety at work in the UK is governed by the Health and Safety at Work etc Act 1974. Under this act a number of regulations have been set up by the responsible government minister to provide more details on specific hazards and other situations.

Regulations in force which are likely to be relevant to hand-mine tunnelling, and HAVS in particular, include Management of Safety and Health at Work Regulations 1989, The Workplace (Health, Safety ad Welfare) Regulations 1992, Construction (Design and Management) Regulations 1994, The Construction (Health, Safety and Welfare) Regulations 1996, The Confined Space Regulations 1997, The Provision and Use of Work Equipment Regulations 1998 and The Control of Vibration at Work Regulations 2005.

Until 2005 there was no specific legislation on HAVS; only recommendations from the HSE, which could be enforced under more general legislation. The 2005 regulations only cover single-axis vibration rather than triaxial effects. As a result, there could be a lot of vibration 'hidden' on the other two axes.

Paul Brereton, noise and vibration engineer with HSE, mentioned an overdue review of vibration recommendations. This will be presented at this year's UK conference on Human Response to Vibration at the Health & Safety Laboratory, Buxton on 20-22 September. But apparently HAVS philosophy is stable at the moment and he sees no change. What will perhaps change, he says, is the information manufacturers provide to contractors according to the European Machinery Directive.

One problem in trying to follow the law whilst conducting a tunnelling operation is interpretation of regulations and guidance, and the fact that much is left to 'doing the most that can reasonably be expected'. Therefore the British Tunnelling Society, with the Pipe Jacking Association and HSE, has come up with guidelines specific to the industry. For now the newly British Standard 6164:2001 (which also has an ISO equivalent) has guidance on vibration in clause 19.

Limit values for vibration exposure have been set. There is an Exposure Limit Value (ELV) for vibration of 5.0m/s^2 A(8) beyond which a worker cannot be exposed under any circumstances. An Exposure Action Value (EAV) of 2.5m/s^2 A(8) is the maximum triaxial vibration exposure normalised over the 8h working period (hence A(8)).

Achieving these limits can be tricky, especially with traditional equipment. Dr Donald Lamont, formerly of the UK Health and Safety Executive, says, "Protection against vibration exposure must be undertaken in accordance with the hierarchy of 'General principles of prevention' in Schedule One to the Management of Health and Safety at Work Regs (see above)."

These are (in hierarchical order):

(a) Avoiding risks;
(b) Evaluating the risks which cannot be avoided;
(c) Combating the risks at source;
(d) Adapting the work to the individual, especially as regards the design of workplaces, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined rate and to reducing their effect on health;
(e) Adapting to technical progress;
(f) Replacing the dangerous by the non-dangerous or the less dangerous;
(g) Developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment;
(h) Giving collective protective measures

priority over individual protective measures; and

(i) Appropriate instructions to employees.

Gloves, which may be provided within (h) in the hierarchy as personal protective equipment are not, says Lamont thought to provide much direct protection other than keeping the hands warm.

North America

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends guidelines and threshold limit values (TLVs) for vibration exposure from hand-held tools based on international standard ISO 5349.

According to information provided by the Canadian Centre for Occupational Health and Safety (CCOHS), ACGIH exposure limits are given as frequency-weighted acceleration that represents a single number measure of the vibration exposure level.

ACGIH has determined acceleration levels and exposure durations to which most workers may be exposed repeatedly without severe damage to fingers (table 1, above), advises that these guidelines be applied in conjunction with other protective measures including vibration control.

Many Canadian jurisdictions do not have regulations concerning vibration exposure. The CCOHS advises that engineering controls, protective equipment and safe work practices should be used to reduce the level of exposure. The TLVs and guidelines recommended by the ACGIH are often used by Canadian agencies in the absence of formal regulations, says the CCOHS.

In the United States, guidelines offered by the National Institute for Occupational Safety and Health (NIOSH) include the TLVs recommended by the ACGIH, the European Union Directive 2002/44/EC, and the American National Standards Institute (ANSI) standard for HAVS introduced in 2006. The new ANSI S2.70-2006 standard sets a Daily Exposure Action Value of 2.5m/s² and a Daily Exposure Limit Value 5.0m/s² as in Europe. The full standard is available through ANSI. The Occupational Safety & Health Administration (OSHA) does not have any regulations for HAVS. The NIOSH does offer criteria for a recommended standard, which dates back to 1989 and can be found online.

Australia

There is no current national code of practice or statute law on vibration control and mitigation in Australia according to risk management consultant Noel Arnold & Associates. Health and safety officers are not 'flying blind', however, since individual state governments and regulatory bodies have not been idle in releasing their own documentation on how best to protect their workers from vibratory occupational health risks such as HAVS, otherwise known as Raynaud's Phenomenon (after the disoverer), and vibration-induced white finger.

Table 1: The ACGIH Threshold Limit Values (TLVs) for exposure of the hand to vibration in X, Y, or Z axis

Total Daily Exposure Duration	Maximum value of frequency weighted acceleration (m/s²) in any direction
4 to less than 8 hours	4
2 to less than 4 hours	6
1 to less than 2 hours	8
less than 1hour	12

In the state of Queensland tunnellers should be familiar with Tunnelling Code 2007, a supplementary document to be read beside the Workplace Health and Safety Act 1995. Coming into action in 2007, amended in 2008 and again in 2010, the code gives practical advice on ways to manage exposure to tunnelling-related risks and is considered relevant until 2017.

As with the European standards, it recommends that certain measures be taken at given levels of exposure. For example, where hand arm vibration is judged to exceed 2.9m/s² the exposed workers must have regular health surveillance as determined by an occupational physician and that 'relevant persons' should ensure that vibration does not exceed 5.0m/s².

A relevant person's responsibilities are given in the Workplace Health and Safety Act 1995 – a legislative document of Queensland drawn on repeatedly by the Tunnelling Code 2007 – as "a person who conducts a business or undertaking has an obligation to ensure the workplace health and safety of the person, each of the person's workers and any other persons is not affected by the conduct of the relevant person's business or undertaking."

Recommended precautions should be familiar to European eyes, and include job rotation, appropriate tool selection and maintenance, training and so on.

Government statutory agency, the Australian Safety and Compensation Council (ASCC) has researched worker conditions and the effect of contact with vibration with the National Hazard Exposure Worker Surveillance (NHEWS) Survey in 2008: vibration exposure and the provision of vibration control measures in Australian workplaces. The ASCC was reformed as Safe Work Australia from 2009 and has plans to shake up guidance on vibration in the workplace as one of its codes of practice priorities. Speaking to *T&TI*, a Safe Work Australia spokesman said, "Safe Work Australia intends to develop two new model codes of practice to provide advice on minimising the hazards of vibration and blood-borne pathogens in the workplace by the end of 2012.

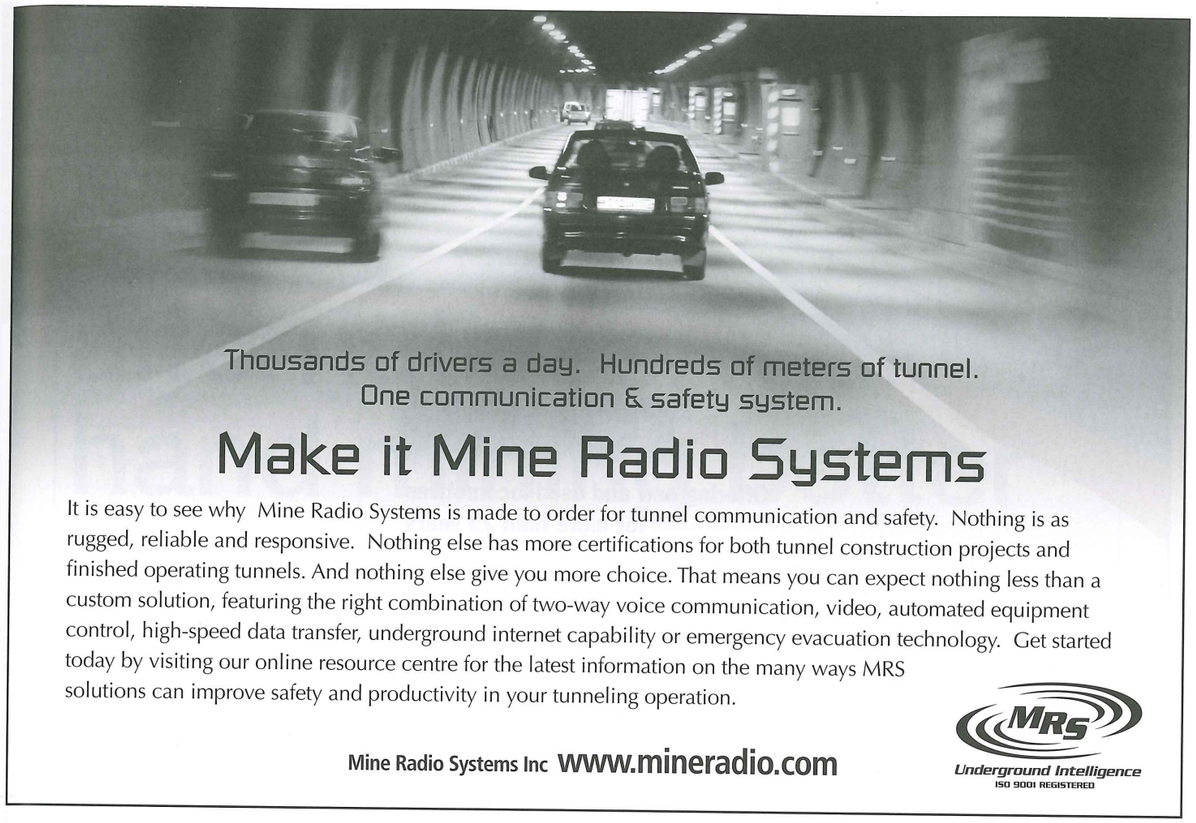
"Both of these codes are to be developed within the framework of the new national Work Health and Safety legislation. We are inviting people from all industries to public consultation workshops to get a range of ideas on the scope, application and approach to these two codes."

Japan

Limited information sourced so far indicate that HAVS or 'Raynaud's Phenomenon' is a matter for assessment of the effects, further research and compensation. Research has been carried out for the Japan Labour Health and Welfare Organisation and the Japanese Ministry of Health, Labour and Welfare, (see Fugiwara et al in Japan Occup Health 2008: 50: pp.75-78) on finger systolic blood pressure testing (FSBP%) related to cold and vibration effects.

Comments include, "In terms of medico-legal aspects, objective recognition of Reynaud's Phenomenon is considered to be most important in judging the syndrome as an occupational disease. Any recognised appearance of 'white finger' as determined by doctor's inspection and FSBP% testing is considered as HAVS in accordance with the Worker's Accident Compensation Insurance Law. If the patient complains of 'blanching attacks' without support from the inspection registration of these cases must be judged as of 'unidentified phenomenon'.

Alex Conacher, Maurice Jones and Nicole Robinson







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Mitigation and alternatives: making hand mining better

A current trend in tunnelling, as in many other industries, is against manual labour, but in many situations hand mining seems the logical first choice until one considers the hazards involved that are arguably greater then those associated with large-section tunnelling. Maurice Jones checks on the current status of the activity, mitigation to improve hand mining, and the alternatives offered by some equipment manufacturers.

The disagreements, to say the least, over whether hand-arm vibration syndrome (HAVS) is a real hazard in tunnelling activities started with the virtually continuous use of pneumatic spaders in hand-excavating pipejack work and some other types of tunnelling. Both the levels of vibration determined to be experienced by miners, and the periods of time over which the tools have been used are deemed in excess of the limits now imposed through safety legislation.

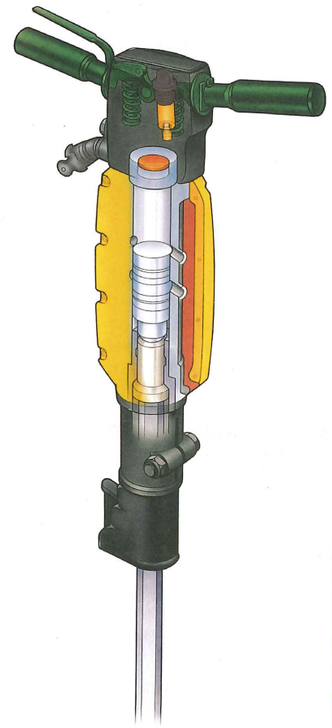
Spaders, by their nature, are used invariably in soft ground, chiefly clay and fill, to dig into and lift away the ground to be excavated. Even though, as it is claimed by contractors and miners, that no case of HAVS (or 'white finger') has been caused by powered hand mining in clay, it is logical that there should be efforts to minimise the total amount of vibration to which miners are exposed, and these are required in some law. Similar manually operated rock drills (hand-held and air-leg) and peckers can also be used in tunnelling, with an associated higher level of potentially harmful vibration, to which the same must apply.

Vibration exposure can be minimised through either using tools generating lower vibration levels or limiting the periods that power tools are used, or a combinations of the two.

Lower vibration

Prompted, it appears, mainly by the do-it-yourself and general construction and demolition markets, there have been efforts to reduce the levels of vibration in manually operated power tools. Manufacturers such as Hilti, Kango and Makita have all been advertising lower-vibration tools in recent years, but these are mainly powered by electric or hydraulic feeds and are not often used underground despite being arguably more efficient than compressed air. It should be possible to provide an electrical supply of suitable voltage or hydraulics from a power pack or take-off from other plant that may be available in the tunnel. A drawback, however, is that it is undesirable to operate standard hydraulic hammers at the sort of angles traditional pneumatic tools are used. Specially designed larger hammers such as scalers (see below) used in drill-and-blast and some demolition hammers are tolerant of this.

Manufacturers and safety enforcers often claim that miners do not understand the operation of more modern, lower vibration, equipment and say that they insist on being able to feel the vibration to believe that the device is working properly. There is clearly a need for education when trying to introduce new equipment and make it more acceptable. In this hand miners should be no different to other tunnel workers to be trained in the use of new equipment.



Above: Cutaway diagram of an Atlas Copco light hydraulic breaker for manual use

It appears that convincing the traditional miner will still be an uphill struggle. "The problem with this one is that really complicated and short sections are actually better done with a gang of hand miners with the old FL22s or 'Germans'", states Dickie Dexter, construction director of tunnelling with Joseph Gallagher. "Oddly these two are still, by a country mile, the best two hand tools manufactured even



Above: **Small roadheaders may be applied to restricted working space such as this Sandvik set-up in a Swiss tunnel enlargement**

with all the new vibration-damped machines, the miners will always try and grab the old machines before the new ones."

Traditional skills

Hand miners are very proud of their traditional skills and rightly so. Just because their efforts are chiefly manual does not mean that they do not require in-depth skills built up through years of experience. And, many contractors value these skills even though, due to diverse circumstances it is difficult to keep them readily available.

Contractors value traditional skills because there are still many circumstances in which hand mining is seen as the most practical or most economic way to progress an excavation. Bill Clowes, construction manager at the MTR Corp in London, and formerly with Bechtel offers the opinion, "The key to successful hand mining is to utilise specialist gangs and not try to and use the TBM crew or 'local labour' in these conditions. In Singapore we bought in an Irish handworks gang to complete cross passage construction, and this was money well spent. Other projects that tried to use local labour with 'main tunnel' supervision struggled both with safety and production. There will always be elements of hand mining in tunnels, and it is important that we maintain the specialist crews and supervision for these works."

Economy is, of course, no excuse for an unsafe practice, but safety considerations might halt a particular means of tunnelling. There are, however, usually alternatives, albeit at higher costs of equipment investment or operational costs.

Patrick Hudd, manager of estimating with Cementation Canada formerly worked in some hand-mining operations in the UK said, "There are not that many, miners nor engineers, who can supervise and safely do timber headings, breakups, etc, which is a shame."

Ronnie Christer, tunnelling manager of contractor Fineturret in Preston, UK, reports, "Fineturret were involved three years ago in repair work to a Victorian tunnel in Somerset. The tunnel carried water from several reservoirs in the Mendips (Hills) to a holding reservoir near Bristol. When the holding reservoir was completely full it allowed the tunnel to be drained and repairs carried out it during a limited period of six weeks."

"The access shaft where the repairs were done was only 2m in diameter and 60m deep. Due to these limitations (maximum size of equipment etc) all the work was done manually, and there were 10 miners on each shift to comply with HAVS regulations. Only two FL22s were used on a rotation system, but the repairs were completed on time. We had an agreed daywork rate with a completion bonus"

Hand mining can also produce a better job in terms of tunnel construction, if the crew is sufficiently skilled. Dexter points out that the Dorchester Link Tunnel was at first proposed as a hand tunnel but was changed to a larger sprayed concrete lined (SCL) drive, resulting in more settlement. Gallagher didn't think it would be accepted as a hand tunnel because of concerns over HAVs. Small excavators were tried instead (see below).

Other considerations

In reviewing the tunnelling system to reduce vibration exposure, other hazards in small-sections must also be addressed, all of which are the subjects of, mainly recently introduced, safety legislation. These include:

- Manual handling – of, as examples, steel supports, lining segments, equipment, and large sacks of construction materials such as cement. Problems include the transfer of loads by twisting the body as well as direct lifting. Where the loads exceed the maximum manual handling limits set down in regulations, and even as good practice in any case, the miners should be provided with lifting devices such as hoists, Tirfors or hydraulic manipulators, whether manual or powered.
- Ventilation – small sections leave little room for standard ventilation ducts so those of smaller diameter have to be used. Compressed air supply has also been used, but this can create another hazard unless treated properly with additional equipment. Gas monitors, including for oxygen levels, must be provided, and possible noxious emissions from, for example, repair materials solvents, must be considered.
- Confined spaces – should a hazardous incident occur, such as a build-up of toxic or suffocating gas, an inrush, fire or collapse, the miners should be able to reach a safe egress point. This is a function of the tunnel section, the distance from the exit, any obstructions in the tunnel such machinery and muck skips, ventilation supply, use of self-rescuer devices and the number of people working in the tunnel.

Hudd claims, "True hand excavation, timber heading, hand-built rings and 'jiggers' are difficult. Certainly in the UK, hand excavation is difficult due to all the exposure monitoring that is required for 'white finger'. The damped jiggers and electric models are not nearly as good as an FL22 or Hausherr/Flotman."



Right: **This Bobcat 324 compact miniexcavator has a retractable undercarriage and a reach of 4.27m**



Above: **Atlas Copco's SB52 hydraulic breaker, here on a miniexcavator, is the smallest in the range at 55kg weight**

Pipe jacking

Being aware of the difficulties of hand mining within small-diameter pipejacking, timbered headings, etc the 'Guidance on the design of hand excavated pipejacks' produced by the UK Pipe Jacking Association together with the British Tunnelling Association and Health & Safety Executive presents a table of dimensions for the use of designers stating acceptable limits. No hand operation below the surface is acceptable below 1200m diameter. Recognising the additional possible hazards of powered equipment in small diameters, the minimum diameter is raised to 1.35m if mechanical excavation or a mechanical erector is used. The only operations not to be avoided in small diameter pipejacks are operator controlled pipejacking of 1.2m diameter, or, if machine erectors are used, above 1.8m diameter.

This guidance places the bias firmly in favour of mechanical excavation, either operated remotely from the surface (i.e. microtunnelling), or within the shield machine at larger diameters. The former places a primary requirement on the reliability of microtunnelling equipment in avoiding breakdowns that require access to the shield machine or cutterhead, and a limit to the length of drives so that, depending on the hardness and abrasivity of the ground, cutting elements do not wear out before the end.

The difficulties of safe egress in small diameters is also recognised in the guidance. Man entry, for whatever purpose, has to be avoided or is not acceptable below 1200mm diameter. Above this diameter the maximum distance to the nearest exist point is set down in stages increasing from 25m at 1200mm diameter.

Miniexcavators

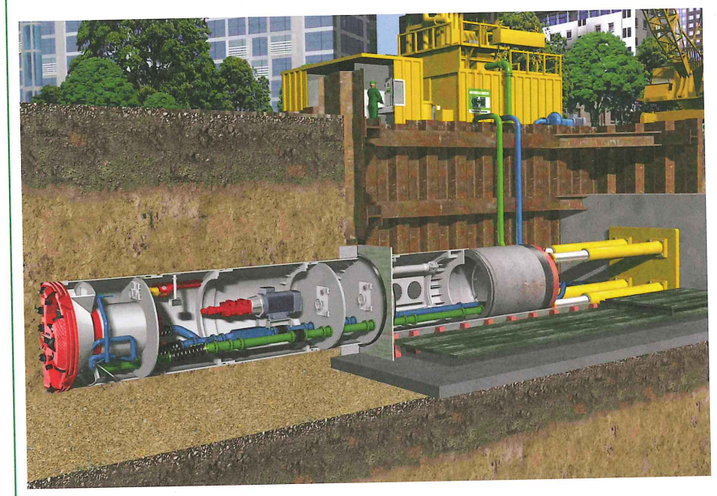
If they can be made to work in the circumstances of the tunnel, and in particular the dimensions, small excavators can eliminate many of the problems associated with hand mining. They can provide a means of excavation, a carrier and/or power source for other equipment such as hydraulic breakers, and a means of lifting support materials into place. However, they have to be 'up to the job' chiefly in terms of power availability, as this is a drawback for many contractors. The standard diesel drives may not be acceptable for ventilation reasons.

Andrew Smith, also of Joseph Gallagher Ltd, says the contractor used a 'Celtic Miner' made by Metal Innovations of Wales when working on the Hampton Pump-out Shaft in southwest London, sub-contracting to Costain, but not very successfully. "But I understand it has been upgraded as regards power since then and we are probably about to use it on Costain's National Grid tunnel work at Willesden to drive launch adits in SCL for the Cat TBM. We are currently using a Schaeff 112 at Eade Road to drive launch adits for the Herrenknecht TBM, which are larger. The Schaeff is too big for the Willesden adits."

Following its use at Hampton, main contractor Costain also hired a unit for work on Southern Water's Brighton project.

In a project to create extra visitor exhibition galleries underground at the England National Mining Museum contractor Amoco (Amalgamated Construction) chose a Celtic Miner 4500 because it can be easily dismantled to be transported in the small mine shaft and reassembled underground.

The Celtic Miner, or CM4500, is only



Above: Hand excavation in pipe jacking can be avoided by complete microtunnelling mechanisations, but it has to be reliable, such as with this Herrenknecht slurry system

1.6m wide, 1.5-1.8m high, and 2.7m long. Its hydraulic power comes from a source that can be up to 350m away. Possible functions include a cutterhead, hydraulic hammer, and support lifting. The maximum dimensions that can be excavated are 5m width by 4.5m height and down to 2.5m. The carrier can turn in a 2.7m radius and climb at 1 in 4 grade.

Dexter says that Gallagher tried a Butor electric excavator for the Dorchester Link Tunnel. The contractor bought one and had it converted into even more compact dimensions as it wouldn't fit into the 3.5m wide excavated, and 3.2m wide spray-lined tunnel, without banging into the tunnel walls but it was still too big. "We ended up with a (Takeuchi) diesel 1.5-t mini-digger which, oddly enough, worked very well, if a little cramped. …. The industry is crying out for something small, heavy, powerful that can spray shotcrete, and dig and shift 'muck at a rate of knots'."

Small-diameter shields can also be equipped with hydraulic backhoes. These have the additional advantages over manual excavation in that the operator is better protected by the shield, especially when digging out the invert.

Cutterheads

Another useful device in replacing hand excavation are rotary cutterheads of the types used on roadheaders, but at a smaller scale. These can be attached to small hydraulic excavators, usually on tracked carriers for more stability, or within small shields similar to backhoes. Provided there is a suitable hydraulic supply, the main consideration is a suitably small but powerful carrier.

Hydraulic hammers

Depending on the working space available, a hydraulic hammer can also be attached to an excavator of suitable size.

For efficient excavation the hammer tool should always be held perpendicular to the rock or ground to be broken and excavated, and ideally with the boom of the carrier held in a position to provide a constant feed force. Failure to do this will lead to increased vibrations through the carrier, perhaps affecting the operator. Zero feed and contact between the hammer tool ('idle' operation) and the ground shield should be avoided at all costs to prevent rapid wear of the tool mechanism. Care of the equipment also avoids excessive use for levering the ground out unless, as with a scaler, the equipment is designed for it.

Excessive reach between the tool carrier and the ground can result in the carrier's hydraulic cylinders working at their maximum extent, which will also increase wearing vibration.

Drill-and-blast

In harder rocks, drill-and-blast may be an alternative, but, again, with hand-operated tools there is a danger of excessive vibration. Single-boom hydraulic, and sometimes compressed air, drill-rigs are available, of the type used in mining to follow metalliferous mineral veins.

Tony Morris, now senior project engineer with Agrium in Canada, and formerly with Cementation, reports driving a 12ft x 12ft (3.66m x 3.66m) starting with an 8ft x 8ft (2.44m x 2.44m) pilot drive to assist in preventing overbreak. Throughout hand-held drills were used in 'moderately hard' rock. "There were no problems with the regulatory authorities," he reports. "Mechanised techniques would not have been cost effective."

Hudd reports, "I was on a job in Somerset (UK) for drill and blast, but blasting restrictions became so limiting we went to hand excavation in mudstone, and made good progress. Jacklegs continue to have a place for small headings, miscellaneous utility work and initial off-shaft developments for sure."

Mucking out

As is well known in tunnelling, it is of no use excavating efficiently if the spoil cannot be removed and transported in an equally efficient manner. This can also present problems in small sections, but, many practical ways of spoil removal have been developed over the years in conjunction with hand mining including rope-hauled pans on tyres or tracks (see separate Tenbusch article in this issue), armoured conveyors fed by gathering-arm or rotary loaders. If the whole length of the tunnel being worked is of small section, the equipment may cause an obstruction .

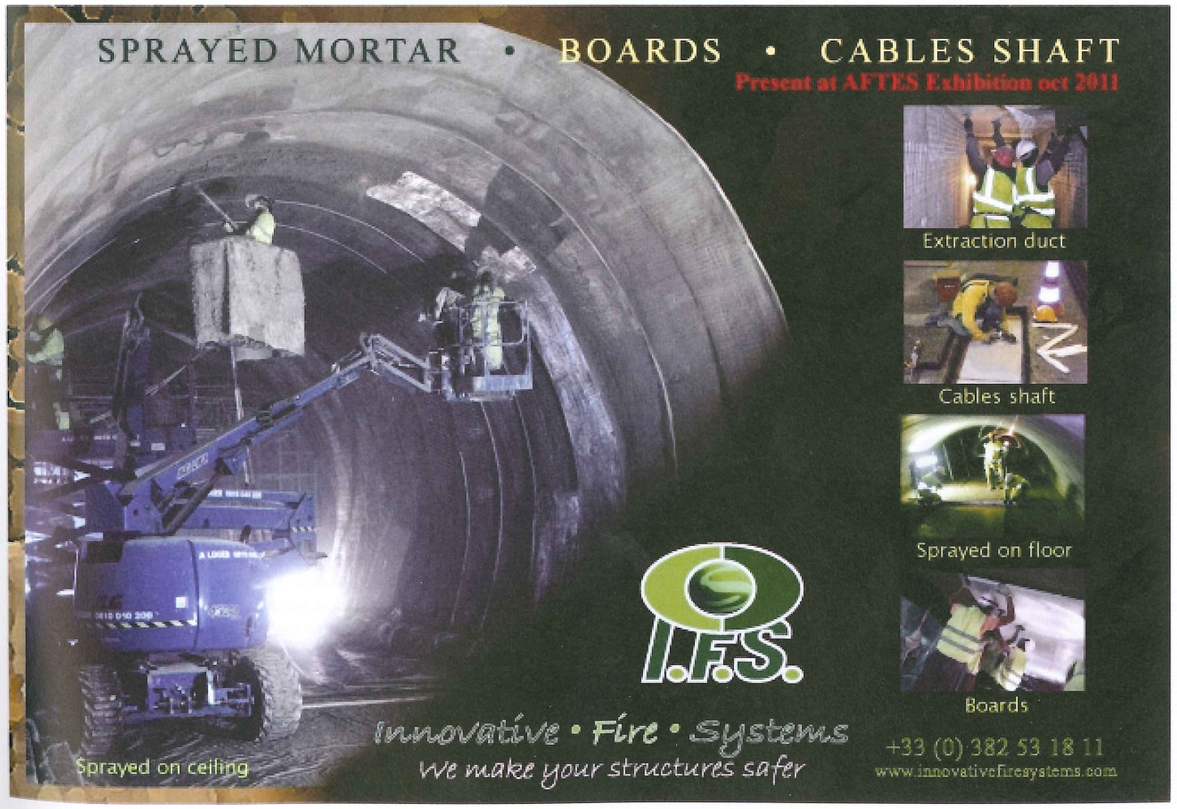
ITC-Schaeff models are available with a loading apron and a chain conveyor running through the centre of excavator that can be adjusted to suit the means of main muck transport.

On the Hampton project mentioned earlier, more efficient clearance of spoil was required so Metal Innovations delivered a Celtic Miner conveyor system and tracked materials transporter to the site, custom-made to work with the CM4500 excavator.

How?

How have you avoided the hazards associated with small-section excavation? And what do you see as the main hazards? Is tunnelling by hand mining virtually dead, at least in some parts of the world, or does it have a future? Do you think safety authorities are tackling these problems in the right way? Let us have your views by writing to the Editor or emailing us on Maurice.Jones@tunnelsandtunnelling.com or John.Young@tunnelsandtunnelling.com.





Lab test for EPB ground conditioning

This article describes the cooperation between the Politecnico di Torino and construction materials manufacturer Mapei, both based in Italy, in the field of laboratory testing of ground to be excavated by EPBM after suitable conditioning, and comparison with actual site conditions

Optimisation of ground conditioning is one of the key parameters to achieve a successful tunnel drive with an EPB shield machine.

The conditioning products and parameters therefore have to:

- Generate uniform face pressure
- Minimise inflow/over-excavation
- Create a homogenous flow path from the tunnel face to the belt conveyor
- Minimise torque and friction

Before the TBM launch, it is strongly recommended to carry out a series of laboratory tests. These should be able to characterise the soil to be excavated and to give a good estimate of the parameters to be used during tunnelling.

For this reason, over the last 10 years, there has been a strong cooperation in research between the laboratory of Tunnelling and Underground Space at Politecnico di Torino (Turin Technical University) and the UTT (Underground Technology Team) of Mapei. This has led to the creation of a laboratory fully-dedicated to ground conditioning tests as well as the development of new laboratory devices and procedures specially designed for use in the tunnelling industry.



Above: Laboratory equipment for simulating EPB operations

Tests

Some of the most important laboratory tests for characterisation of conditioned soil are presented and discussed as follows.

Foam half-life

The half-life of foam (t1/2) is the time required for 50 per cent of the water used to generate the foam to drain away. The half-life depends upon the foaming agent concentration in water and the foam expansion ratio (FER). The longer the foam half-life, the higher its durability and efficiency when mixed with soil.

Slump tests for conditioned soils

In order to quickly characterise the conditioned ground, it is possible to carry out standard concrete-type slump tests on the material. In a standard mixer, the proportioned amounts of ground and foam solution are mixed together in order to achieve the desired FIR (foam injection ratio). The slump tests allow ta visible check and measurement of the consistency of the conditioned ground and to determine whether it is appropriate to EPB operation.

Permeability test

Soil permeability is a key parameter for good conditioning, particularly when working below the water table. Only conditioned ground with low permeability facilitates the correct management of the pressure to the face in the presence of water and prevents possible water inflow into the excavation chamber.

For this assessment it is not possible to use a standard permeability test since this procedure requires a constant water flow through the sample. In the case of conditioned soils, the flow washes away the bubbles thus changing the results that can be obtained and that are significant for the technological application of an EPB machine. To get significant results a modified permeability test should be carried out. In the laboratory of Politecnico di Torino a specific procedure with the measurement of the time required by a pre-defined amount water to pass through a sample has been set. A series of tests have shown the feasibility of the procedure.

Wear test

To ascertain if the adopted conditioning is able to reduce both the wear on the metallic parts of the machines and the friction of the muck, a test device, where a disk is turned inside the soil at a constant speed for a pre-defined time, has been developed in the laboratory and the test procedure has been defined. The test is carried out with the measurement of the loss of material of the test disk (made of brass or aluminium) before and after the test and the measurement of the applied torque. This test procedure has been shown to be feasible and to permit a good comparison between different conditioning sets.

Simulation of the ground extraction by a screw conveyor

This test allows evaluation of the suitability of conditioned materials to be extracted from a chamber under pressure by means of a screw conveyor. The experimental apparatus available at the laboratory (the only one in Italy, and among the few available in the world of this type) consists of a metallic cylinder of nominal diameter 600mm that is coupled to a 1.5m-long screw conveyor. The apparatus is equipped with several sensors to measure the pressure in the tank, along the screw conveyor and the torque on the screw.

Basically this test allows checking of the efficiency of the ground conditioning parameters found during the slump test on a larger scale with a procedure closer to real action of an EPB machine.

The ground is considered to be conditioned correctly if the screw conveyor is able to extract soil constantly, and the pressures registered along the screw decrease regularly from the cell closest to the chamber to the last one. Furthermore this test assesses the suitability of the conditioned soil to apply a regular pressure and to traverse the screw conveyor and measure the reduction in torque.

Some case histories

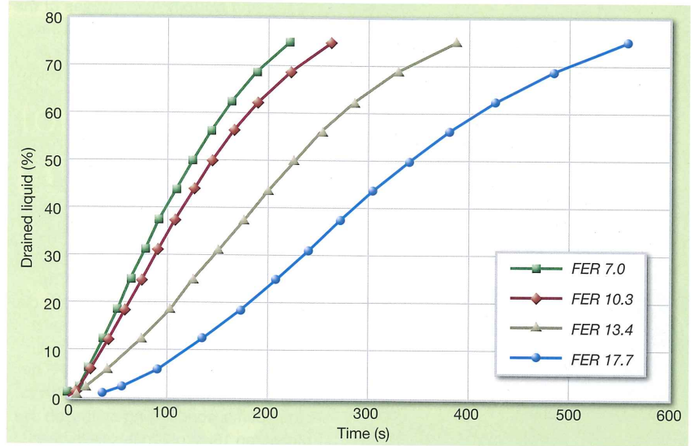
During the co-operation between Mapei UTT and Politecnico di Torino, several tests have been carried out with samples of soil received from mechanised tunnelling job sites located all around the world.

From these tests it is possible to establish a number of correlations between the results achieved in the laboratory and what is actually used on the EPB on site. In the following projects, initial trials were carried out in the laboratory in Turin and subsequently it was possible to check directly on the TBM if the parameters were appropriate for real EPB operation.

Maldonado water tunnel in Buenos Aires

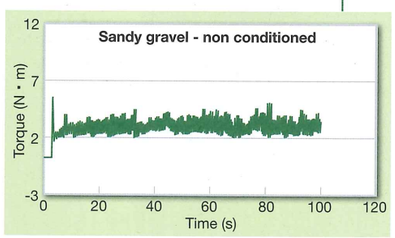
Client: Gobierno de la Ciudad de Buenos Aires
Contractor: Ghella Costruzioni
About 10km of tunnel have been excavated with two EPB shield machines. Several different and severe geological conditions have been excavated, including both very fine and sticky soils and gravels with high-pressure water present.

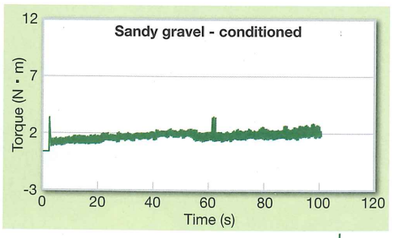
After the laboratory tests, the product Polyfoamer FP was chosen, with optimal parameters including concentration at 2.0 per cent, FER 12 and FIR 40 per cent. The use on the EPB has completely confirmed the parameters established in Turin: FER varied from 10 to 14 and FIR between 35



Above: **Figure 1, results obtained from half-life tests using the same foaming agent liquid for differing foam expansion ratios or FERs**







Below left: **The wear test; it is possible to see the position of the torque-meter and the tank where the soil is inserted;**
Below: **Figure 2, example of measured torque during the wear test without conditioning and with conditioning**

The authors

Daniele Peila, Luca Borio and Sebastiano Pelizza are all with the Department of Engineering, Land, Environmental and Geotechnology of Poltecnico di Torino (Turin Technical University, Italy - http://areeweb.polito.it/ricerca/tusc/index_en.htm), while Enrico dal Negro, Alessandro Boscaro and Richard Schulkins are all with the Underground Technology Team of materials manufacturer Mapei, of Milan.

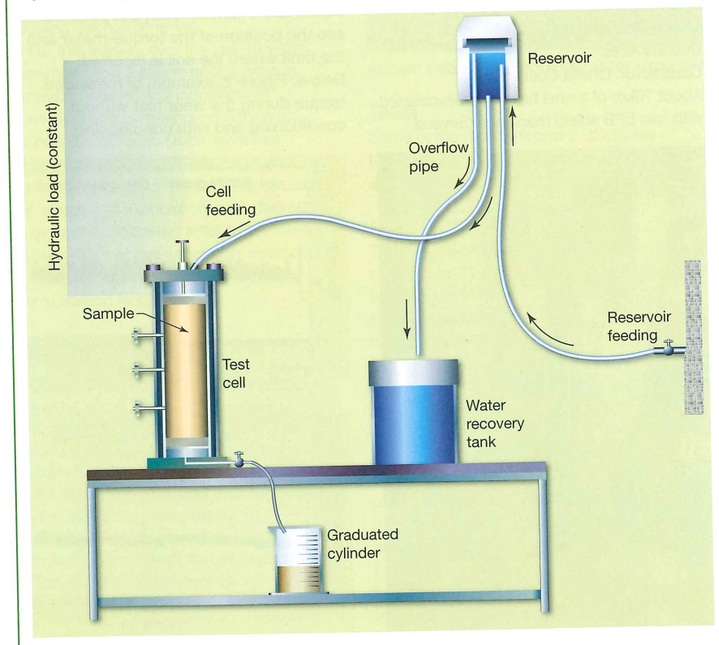




and 60 per cent, dependant on the geological conditions at that point in time.

These subtle variations allowed the optimisation of the EPB operations in terms of advance speed, torque, wear reduction, and to minimise the foaming agent consumption.

Below: The modified permeability test layout and equipment



Left, top and bottom: Two images of the ground from the Buenos Aires job site, before and after the conditioning with the foaming agent Polyfoamer FP (FIR 40 per cent, FER 12)

Metro Line C, Rome

Client: Roma Metropolitane

Contractor: Metro C Spa (joint venture of Astaldi, Vianini Lavori, Ansaldo STS, CMB and Consorzio Cooperative Costruzioni).

Two parallel tunnels are under construction in Rome using four EPB machines. The geological conditions include generally clay and silty ground with underground water.

The laboratory tests were carried out with the foaming agent Polyfoamer FP by Mapei, and provided useful information to set the optimal conditioning on the job site.

More than 18km of tunnels have been successfully excavated proving the compatibility between the ground and Polyfoamer FP. The parameters established in the laboratory tests were optimised on the EPB (in particular the distribution of the foaming solution among the injection lines) and promoted very high production (up to 25-30m/day), with consumptions of foaming agent lower than 1l/m³ of excavated soil.

Conclusions

The experience accumulated during the recent years of co-operation between the UTT of Mapei and Politecnico di Torino,





Above: The two image show the results of conditioning testing on Metro C Spa's Rome Metro Line C (FIR 40 per cent and FER 12)

proves the need for a series of laboratory technical tests to be carried out before the launch of an EPB machine. This allows us to get basic information about:

- The products to be used for the ground conditioning (foaming agents and possibly polymers)
- The parameters relating to concentration, FER and FIR to be set in the machine

The laboratory tests also give the designer and or the contractor the possibility to estimate the costs to be considered for the ground conditioning operations during tunnelling before the TBM starts.

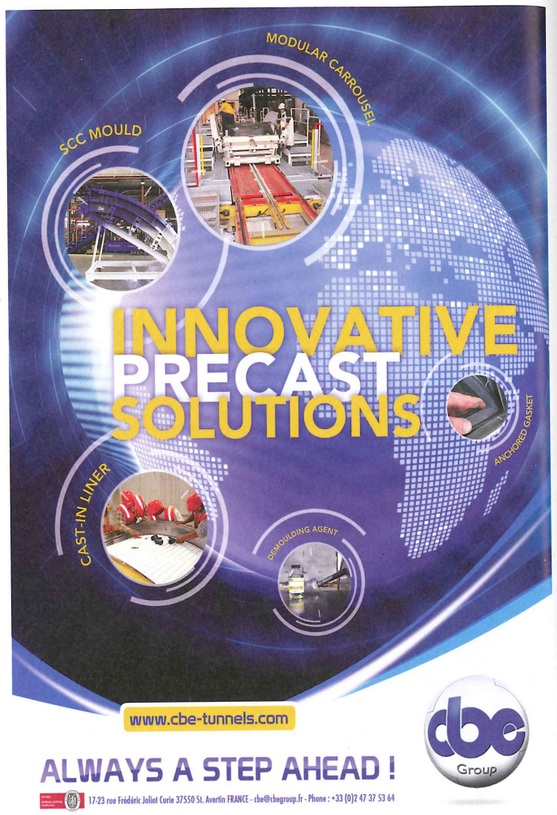
The use of the appropriate products and parameters minimise the possibility of facing unexpected problems during tunnelling operations.

These could otherwise lead to expensive and dangerous (for workers) delays due to, for example, the replacement of tools. When no intermediate shafts are scheduled in the design, the previous knowledge of the soil and its conditioning is even more vital to success.

This has been confirmed now by several TBM projects. It has been possible to show a strong correlation between the products and conditioning parameters established in the laboratory tests and their ultimate use on the TBM.

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Assessing face stability

Spyridon Konstantis of UK-based consulting giant Arup was a runner up in the British Tunnelling Society 2011 Harding Prize with this paper on the probabilistic assessment of face stability conditions for shallow tunnels in soft ground. *T&TI* presents this article drawn from the paper he presented

Face stability is a key factor for shallow tunnels excavated in urban areas, under severe environmental constraints and in many cases through challenging and difficult ground conditions.

Tunnel face instability may lead to unacceptable relaxation of the advance core (Lunardi, 2000) and also, in extreme cases, to partial or total face failure (ITA-AITES, 2006).

The factors that influence the face stability conditions are associated with the geometrical characteristics of the tunnel and the hydro-geological/geotechnical conditions of the ground.

The assessment of face stability conditions and necessary support pressure requires in principle three-dimensional (3D) numerical analyses. However, these analyses have a number of certain drawbacks mainly associated with complicated input preparation and output presentation, time consuming analysis, multiple simulation stages and incompatibility between improved accuracy and level of knowledge of ground conditions (Kavvadas, 2005).

In conceptual studies and preliminary design stages where available geotechnical data are limited and in many cases parametric analyses have to be carried out, the use of simple and practical assessment tools would lead to a significant reduction in numerical effort/analytical studies and associated time and cost.

The outcome of the present work is a series of dimensionless graphs that can be used to preliminarily assess the support pressure that needs to be applied on the tunnel face to ensure stability conditions.

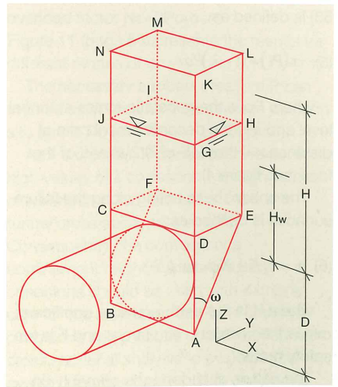
Face stability assessment methods

In the literature, there are many analytical methods available for assessing face stability conditions (Guglielmetti et. al., 2007). Most of these methods make use of limit equilibrium models as well as upper and lower bound theorems of plasticity.

In the present work, three different analytical methods have been used: a) the 3D wedge limit equilibrium model with side friction, b) the convergence-confinement method and c) a combination of the two.

3D wedge limit equilibrium model with side friction – Silo load

This method was originally introduced by Horn (1961) and has its basis on the silo theory by Janssen (1895). Anagnostou and Kovari (1994) have extended it and in the international literature it is now well known as Anagnostou & Kovari method.



The failure mechanism comprises a wedge ahead of the tunnel face and a prism above it (see figure 1, below).The loads acting on the wedge are:

- Its self weight,
- The resulting normal and shear forces along the failure surfaces ADE, BCF and ABFE,
- The face support applied on ABCD
- The overburden load acting on the interface CDEF.

The methodology for defining the necessary support pressure P is based on the wedge limit equilibrium and is described in detail in Anagnostou and Kovari 1994.

This method assumes that the ground on the wedge and the prism is homogenous. Anagnostou and Serafeimidis (2007) have extended the method to account for heterogeneous, layered ground on the tunnel face.

Convergence-confinement method

The excavation of a tunnel induces ground deformations and causes changes in the stress regime of the surrounding ground as a result of the gradual reduction of the in situ stress (Po). This stress relaxation is depicted in figure 2 (page 54) and can be expressed as:

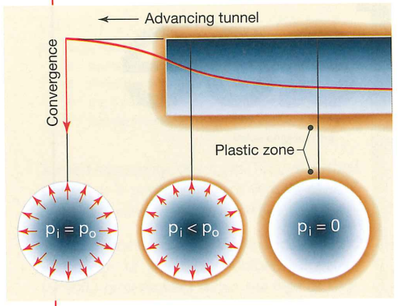
(1) $Pi = (1 - \lambda)Po$

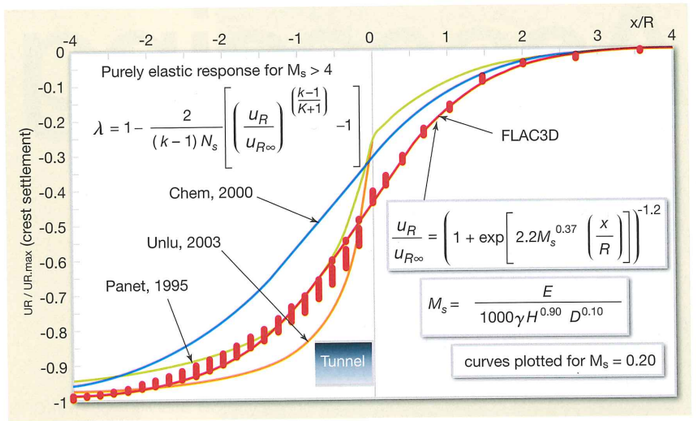
where Po is the isotropic geostatic stress and λ is the deconfinement ratio.

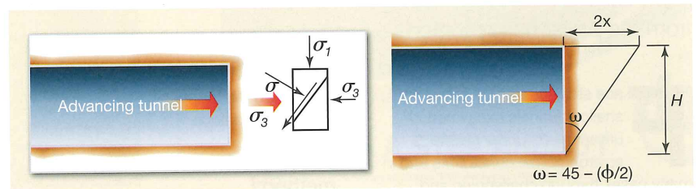
Pi represents the self supporting mechanisms of the ground with the form of a fictitious internal support pressure.

Figure 3 (page 54) shows the longitudinal deformation profile of an advancing tunnel, where the ratio of the crest settlement ur to the maximum crest settlement ur,max

Left: Figure 1, Tunnel face failure mechanism (Anagnostou & Kovari, 1994)







Above: Figure 2, Gradual reduction of in situ stress Po relative to the distance from the advancing face of an unsupported tunnel (Hoek, 2007)
Right, top: Figure 3 Longitudinal deformation profile of an advancing tunnel (Kavvadas, 2005).
Right, bottom: Figure 4, Stress state in the advance core of an unsupported tunnel face (Kavvadas, 2005)]

(ur/ur,max) can be related with the distance from the advancing face (x/R).

The stress state at the unsupported face of an advancing tunnel represents, in a simplified approach, uniaxial compression conditions (see figure 4, right).

According to Kavvadas (2005), the initial safety factor FSo of an unsupported tunnel face can be expressed as:

(2) $$FSo = \frac{\sigma_{cm}}{\sigma_1} = \frac{2}{(1-\lambda)Ns}$$

where Ns=2Po/σcm is the overload factor, σcm=2*c*cosφ/(1-sinφ) is the ground strength and σ1=(1-λ)Po is the overburden stress at distance x=H*tan(45-φ/2)/2 ahead of the face.

If support pressure σ3 is applied on the face, the ground strength increases to σc=σ3*tan2(45+φ/2)+σcm and the stress state at the face represents triaxial conditions (Kavvadas, 2005). Assuming that λ is not affected by the application of the support pressure, the improved safety factor FS is:

(3) $$FS = \frac{\sigma_c}{\sigma_1} = FSo + \frac{1}{(1-\lambda)}\left(\frac{\sigma 3}{Po}\right)tan^2\left(45 + \frac{\phi}{2}\right)$$

The critical value of the deconfinement ratio λcr is defined as (Kavvadas, 2002):

(4) $$\lambda_{cr} = 1 - \left(\frac{2}{1+k}\right)\left(\frac{Ns-1}{Ns}\right)$$

where k=tan2(45+φ/2) ≥ 1

- If λcr≥1 (elastic ground) or if {λcr <1 (elastoplastic ground) and λ≤λcr}, then no plastic zone is developed around the tunnel (elastic conditions)
- If λcr <1 and λ>λcr (elastoplastic ground), then plastic zone is developed around the tunnel (plastic conditions)

3D wedge limit equilibrium model with side friction – Deconfinement load

This method is based on the Anagnostou and Kovari method. The main differences pertain to the definition of the overburden load and the shear stresses on the failure surfaces (Kavvadas, 2002).

The overburden vertical stress σv acting on the interface CDEF (see figure 1, page 53) is defined as:

(5) $$\sigma_v(Pi) = (1-\lambda)Po$$

where Po is the geostatic stress at tunnel level and λ is the deconfinement ratio at distance x=H*tan(45-φ/2)/2 ahead of the face (see figure 4).

The shear stress acting along the failure surfaces is defined as:

(6) $$\tau_f = c/F + K\sigma_{vo}\tan\phi/F$$

where K is the earth pressure coefficient, σvo is the vertical in situ stress and F is the safety factor.

The nature of K depends primarily on the stress relaxation in the advance core. In front of the advance core, the stress state represents conditions at rest Ko (see figure 2, above). Due to the radial pre-convergences that start to develop in the advance core, the stress state could be assumed to represent active earth pressure conditions Ka. In the present work, however, Ko was adopted in the parametric analyses.

Tunnel Stability Factor

The Tunnel Stability Factor (TSF) has been proposed by (Mihalis et. al., 2001) for the assessment of behaviour of underground openings in weak rock conditions and is defined as:

(7) $$TSF = \frac{\sigma_{cm}}{\gamma H^a D^{1-a}}$$

where σcm is the ground strength, λ is the ground unit weight, H is the height of overburden and D is the equivalent tunnel diameter.

Probabilistic analyses

The probabilistic analyses were carried out with the software @Risk (www.palisade.com) and Monte Carlo simulation was used as the sampling technique for the uniformly distributed random variables.

The following cases were examined:

- Tunnel diameter D=4m-10m
- Overburden heights (ground level to tunnel crown) H=5m-30m
- c=5KPa-25KPa
- φ=20°-35°
- Ko=1-sinφ
- Dilatancy angle ψ=0°-φ°/6
- E=15MPa-60MPa
- ν= 0,15-0,25
- γ=18-22 KN/m³

According to Mollon et. al. (2009), the assumption of negative correlation between c and φ gives greater reliability of the tunnel face stability. In the present work, however, c and φ were assumed to be uncorrelated.

The ground water table Hw (see figure 1, page 53) was taken into account only in the Anagnostou and Kovari method and was treated both as random and independent variable.

Moreover, no seepage forces were considered on the tunnel face (zero hydraulic gradient).

Safety considerations

The analyses were performed for unity safety factor (FS or F=1). This approach is in accordance with the general framework of EC7 that requires Design Resistance Rd≥ Design Effect of Actions Ed.

In essence, the tunnel face can be considered as a vertical slope. In EC7 the design requirements for the overall slope stability are defined through the GEO and STR Limit States that concern failure (ULS) or excessive deformation (SLS) of the ground and/or of any supporting structure, respectively.

The methods adopted here for the assessment of face stability conditions do not consider the structural contribution of the support systems but only the resulting pressure, hence the STR limit state is not relevant.

Moreover, the methods are based on failure mechanisms rather than deformation driven modes.

Consequently, the overall stability of the tunnel face can be considered here as a GEO ULS situation.

The ground parameters are considered design values in accordance with EC7 and the partial material factors depend on the Design Approach (DA) adopted.

Results

In the following graphs, the exponent a of the TSF was derived through the correlation coefficients of the input random variables for the output support pressure P, i.e. through the relative impact of the tunnel diameter D and the overburden height H to the support pressure P that has to be applied on the tunnel face to ensure stable conditions.

3D wedge limit equilibrium model with side friction – Silo load

The results for dry conditions (Hw=0) (Figure 5) present a very well determined trend of behaviour. It can be observed that the scatter increases with the reduction of the TSF. The smaller the TSF, the wider the range of required support pressure ratio P/c, thus the bigger the uncertainty and the lower the reliability. According to the graph, no face support pressure is required to ensure stability conditions for TSF values greater than 0.35.

In order to determine the exponent a of the TSF for the case of ground water conditions, a series of analyses were carried out for Hw={H, 3H/4, H/2, H/4, H/8). In the case of Hw≠0, the TSF exponent a can be expressed as a function of Hw/H (see also figure 6, right):

(8) $$a = \ln\frac{(Hw/H)}{0.0356}\Big/3.8833, Hw \neq 0$$

In figure 7 (right) the ground water table Hw was treated as a uniformly distributed random variable. It can be observed that the range of P/c is relatively wide for TSF values smaller than 0.5.

In order to reduce this range, Hw was treated as an independent variable (Mihalis et. al., 2009). Figure 8 (right) shows the results for five different ratios of Hw/H.

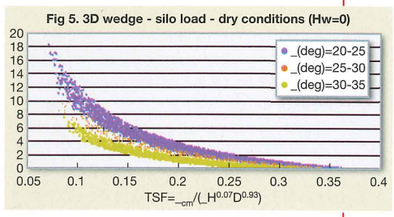
The P/c range can be further reduced by considering ranges of φ for specific ratios of Hw/H. Figure 9 (right) shows the results for Hw=3H/4.

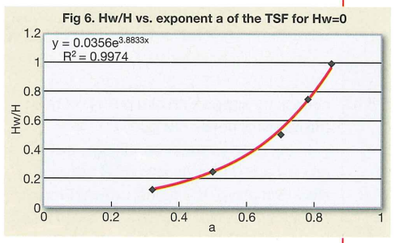
Convergence–confinement method

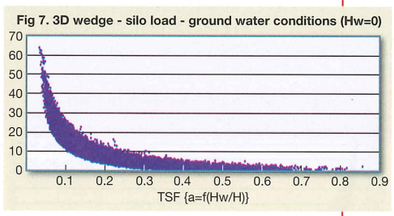
The results for elastic conditions are presented in figure 10 (page 56). For the plastic conditions it was not possible to correlate the ratio P/c with the TSF. However, λ can be correlated with the overload factor Ns=2Po/σcm. Figure 11 (page 56) presents the results for different ranges of φ.

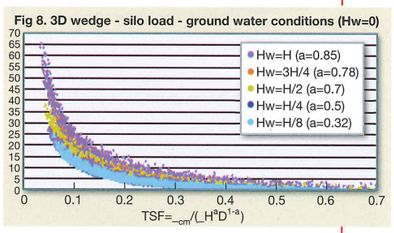
The necessary support pressure P can then be estimated as a percentage of the in situ stress Po (see figure 12, page 56).

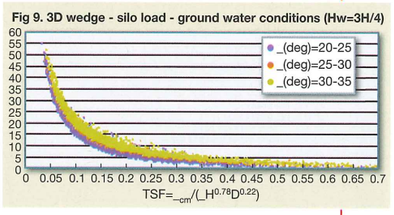
As λ increases, P decreases. However, high values of λ correspond to high values of Ns which in turn are associated with tunnel cross sectional instability. Consequently, the convergence - confinement method under plastic conditions should be used with extreme care for the assessment of face stability conditions and must be accompanied with cross sectional analysis to evaluate the overall behaviour and stability conditions of the tunnel. The results of the probabilistic analyses for elastic conditions are given in figure 13 (page 56).











Application

The application concerns a typical tunnel of D=7m diameter and an overburden height above the tunnel crown of H=20m, excavated through a ground mass with cd=15Kpa, φd=26o and γ=20KN/m³. The

deformability parameters E and v are both within the value range of the examined cases. According to figure 5 (page 55), TSF=0.32 and P is close to zero for the case of the 3D wedge model-Silo load. Following the convergence-confinement method under elastic conditions (figure 10, below), we get TSF=0.12 and P/c=5.5~7.5, hence the necessary support pressure P must be in the range of 82.5-112.5KPa.

Finally, for the 3D wedge model-deconfinement load under elastic conditions (see figure 13, below), we get TSF=0.165 and P/c=3~4.5, hence the necessary support pressure P must be in the range of 45-67.5KPa.

In the ground water conditions, the ground water table is assumed to be Hw=15m above the tunnel crown. From equation 8 and for Hw/H=0.75, a=0.78 and therefore TSF=0.15. From figure 7 (page 55), P/c=5~15 which means that P must be in the range of 75-225KPa. From figure 8, where Hw is treated as an independent variable, we get P/c=8-14 for the same situation and therefore P must be in the reduced range of 120-210KPa. By considering ranges of φ for ratios of Hw/H (figure 9, page 55, for Hw=3H/4), we get P/c=10-13 and the range of P for the same situation can be reduced to 150-195KPa.

Fig 10. Convergence - confinement (elastic)

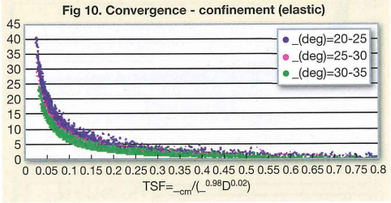


Fig 11. Convergence - confinement (plastic)

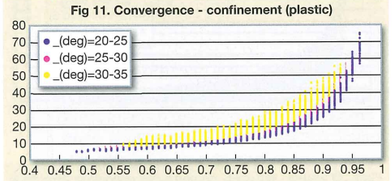


Fig 12. Convergence - confinement (plastic)

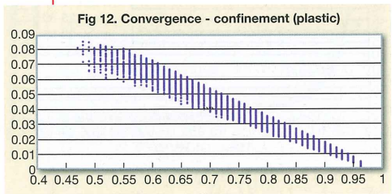
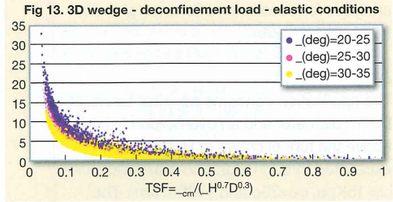


Fig 13. 3D wedge - deconfinement load - elastic conditions



Conclusions

In the present contribution, probabilistic dimensionless graphs have been produced, based on three different analytical methods, for the preliminary assessment of face stability conditions and necessary support pressure for shallow tunnels in various homogenous soft grounds.

The results from all three methods present a well-determined trend with clear upper and lower value bounds.

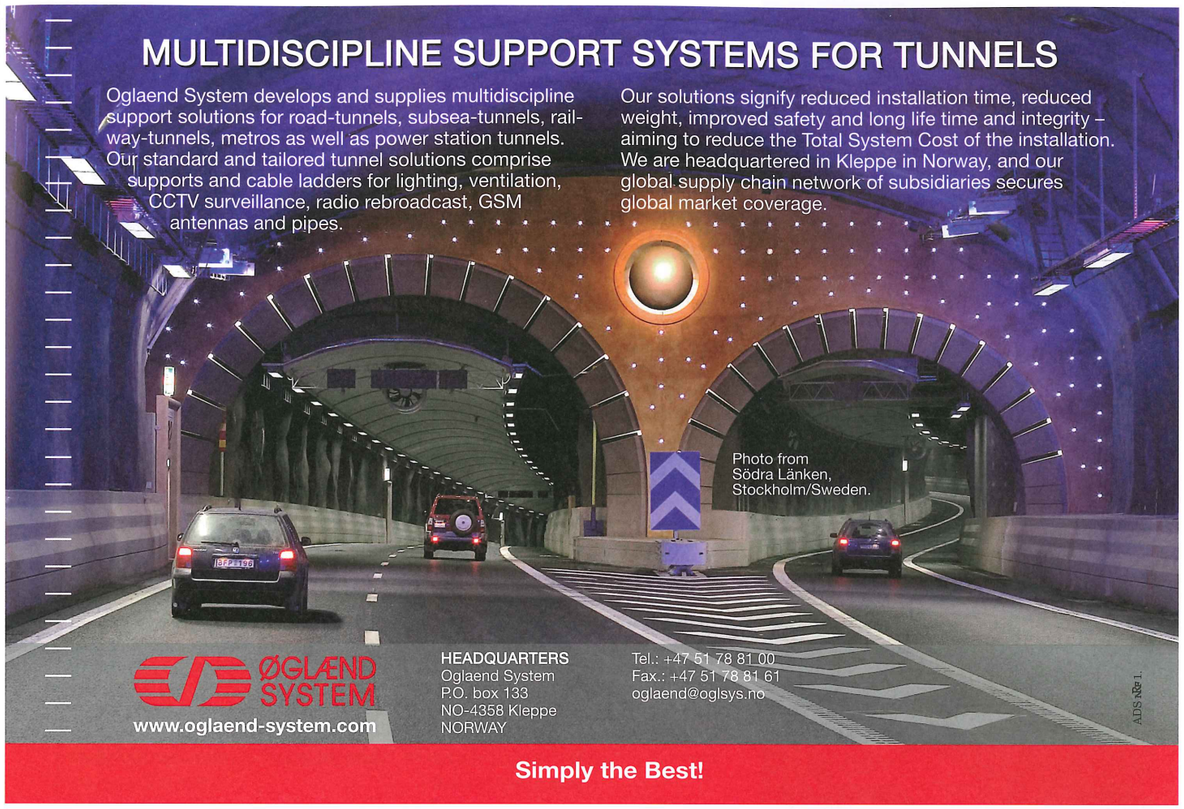
The differences in the range of the necessary support pressure P can be attributed to the nature and basis of each analytical method.

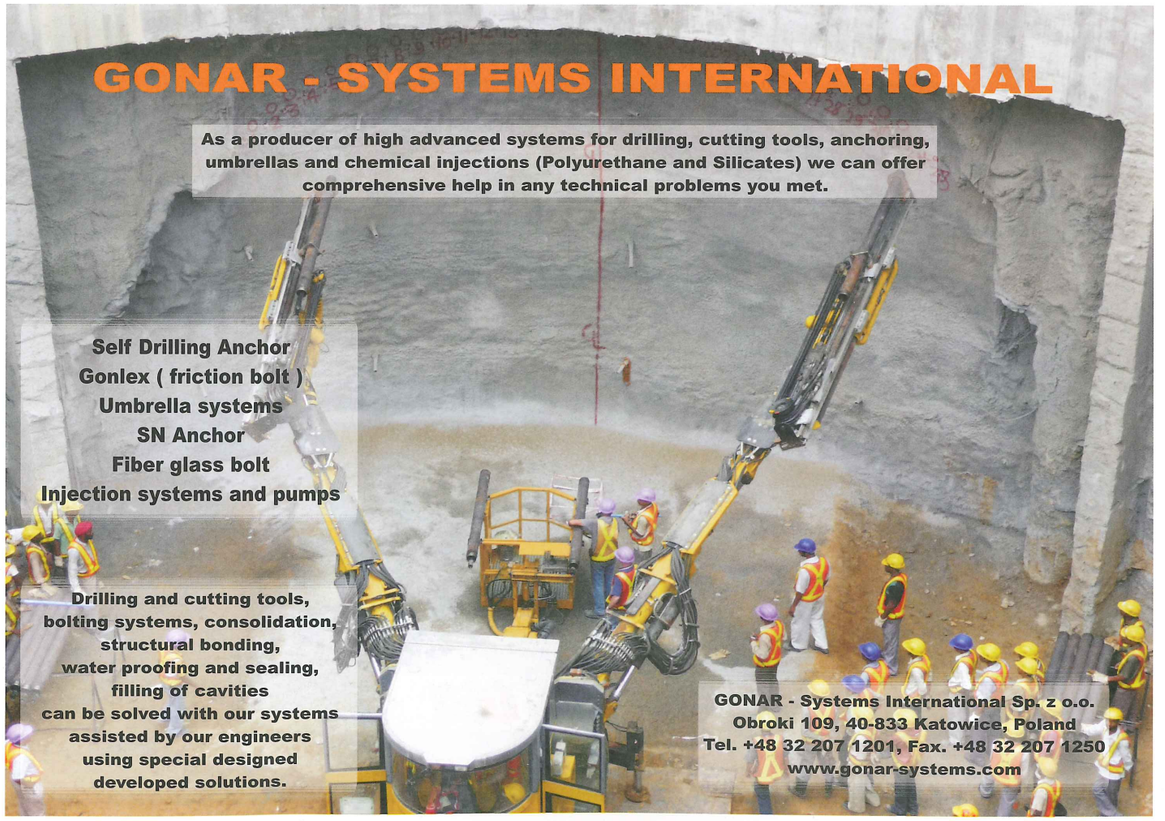
The next step will be to statistically process the results and validate them through case histories and 3D numerical analysis in order to produce practical design charts.

These charts could be used in conceptual studies and preliminary design stages saving a significant amount of effort and resources.

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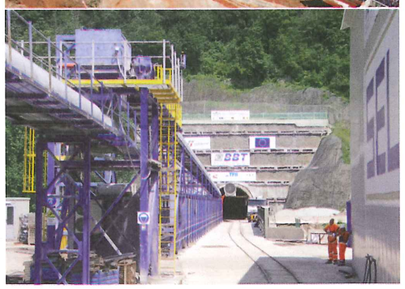
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Basic tunnelling still a viable method

Al Tenbusch of small-bore tunnelling equipment manufacturer and supplier Tenbusch of Lewisville, Texas, describes the two main methods of hand mining and essential considerations

When the term hand mining is used, we know that we are talking about some type of tunnelling. For those who have never been in a tunnel, digging a tunnel by hand conjures up images from World War II movies where the prisoners of war are escaping.

In modern construction practice 'hand mining' is a viable and cost-effective method of constructing a tunnel, but there are some limitations.

Hand mining will not be viable where the tunnel is too small for manned entry or too large so the face of the tunnel becomes unstable. Instability of the tunnel face is a function of the soil cohesion properties and groundwater effects. Hand mining is normally limited to reasonable ground conditions. Some groundwater can usually be tolerated, especially if the tunnel is constructed up-grade.

In order to discuss the methodology of hand mining, it is helpful to focus on the structure of the tunnel and the utility for which it will be used.

Depending on the ground, excavation in 'hand mining' can literally use hand tools (even trowels have been used to finish the profile) or hand-held powered spaders for example. In larger sections a device such as a backhoe excavator could be used.

Some tunnels are constructed using the utility pipeline as the structure itself whereas others are constructed by inserting the utility pipeline into a larger diameter liner. The following materials can be used for a tunnel liner and/or pipe:

- Liner plate,
- Beam and lagging,
- Corrugated metal pipe,
- Steel casing,
- Concrete pipe,
- Wood box tunnel.

There are specific job-site-related parameters including ground conditions that will dictate which structure is appropriate. However, hand mining is normally suitable for all the support materials listed above.

Hand mining is safer and more efficient if accomplished by using a tunnel 'shield'. Figure 1, below, shows a typical articulating tunnelling shield used for hand mining. Such a shield serves many purposes:

- It provides protection for the men as they work;
- Can be configured to allow for steering of the tunnel – both vertically and horizontally;
- Provides a strong and rigid mounting point for excavation tools;
- And provides structure to locate material handling equipment such as conveyors.

In addition, 'sand shelves' may be introduced at the face as part of the tunnelling shield to increase the stability of the tunnel face and further protect the men. Figure 2, below, shows a hand mining tunnelling shield with sand shelves.

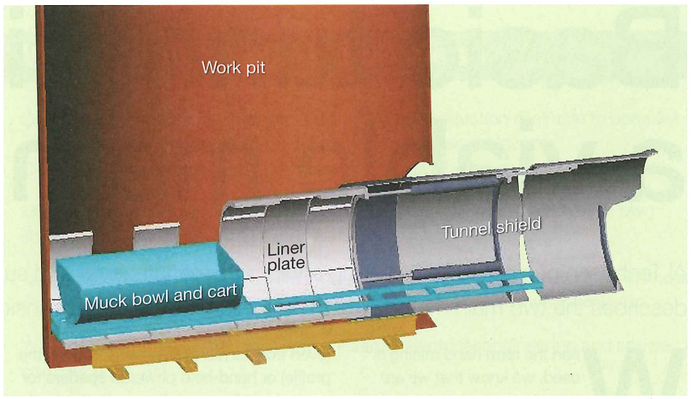
It is important to realise that hand mining will progress by one of two methods:

- Jacking the pipe (pipe jacking) – Insertion of the advancing string of new pipe (as is the case with steel casing or concrete pipe) section by section from the insertion pit;
- Liner plate/beam and lagging – advancing the shield forward by pushing off the assembled tunnel liner product (as is common with liner plate and beam and lagging tunnel structures) – shown in Figure 3, page 60.

Below left: Figure 1, a typical articulating hand-mining shield of 48in (1.22m) diameter; Below right: Figure 2, hand mining tunnelling shield equipped with sand shelves, 99in (2.51m) diameter







Right: Figure 3, cutaway view of a typical hand mining liner-plate application

The following is a comparison of the two hand mining methods.

Jacking the pipe/pipe jacking:

- New pipe is jacked length by length as the men excavate the face from within the protective shield.
- The shield has steering capability to maintain grade and alignment.
- The jacking equipment is substantial and requires a sizable work pit/drive pit.
- The jacking equipment must have a stable backstop to push against.
- Jacking the pipe string typically requires the use of a lubricant to minimise the skin friction encountered as the pipeline is pushed into place.
- When the tunnel is complete the annular space surrounding the pipeline must be filled with grout.
- Several materials are available for pipelines including: clayware, polymer concrete, reinforced concrete, steel, and ductile iron.

Liner plate/beam and lagging (as shown in figure 3):

- The new liner plate is installed one ring at a time as the tunnel is advanced.
- The crew excavates the face from within the protective shield.
- The shield is advanced by hydraulic cylinders within the shield that push against the most recently assembled liner plate ring,
- The shield has steering capability to maintain grade and alignment,
- Installation does not require the use of a jacking unit,
- The work area must be large enough to launch the shield and allow for the entrance and exit of both the men and the materials.
- Liner plate installation does not require the use of a lubricant.
- The installed liner plate is typically grouted in place at the end of each shift or work day.

When performed properly, hand mining is a viable, safe, and cost effective means of tunnel construction.

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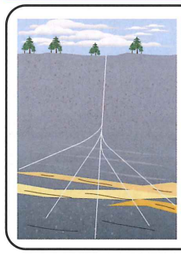
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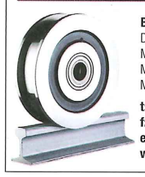
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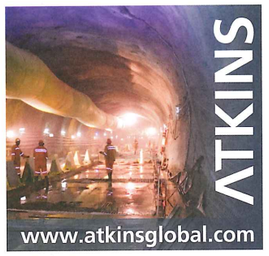
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BRITISH TUNNELLING SOCIETY

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dates & events

18-20 SEPTEMBER 2011
6th European Federation of Explosives Engineers (EFEE) World Conference, Lisbon
Corinthia Hotel. Programme includes an exhibition, educational workshops, dinner & partner activities with technical sessions on EU directives and harmonisation work, health, safety, environment, shot hole development, project experiences, blast design and training. More from Tyler Events on email efee@tylerevents.co.uk, tel. +44 (0)1509 631 530 or see http://www.efee.eu.

19-23 SEPTEMBER 2011
Hydropower Africa 2011, Johannesburg, South Africa
Hydropower Africa 2011 is a niche meeting forum where comprehensive presentations, panel discussions and focused sessions will address the issues surrounding the financing and the implementation of hydropower projects in Africa. For further information, call: Nicolaas Loretz, Tel. +27 21 700 3555.

26-30 SEPTEMBER 2011
World Road Congress of the World Road Association (AIPCR/PIARC), Mexico City, Mexico
Includes a committee on road tunnel safety. For more information tel.: +52 (55) 5148 7500, Email: expo@aipcrmexico2011.org or see www.aipcrmexico2011.org

5-7 OCTOBER 2011
2nd Int Seminar on Safe & Rapid Development in Mining, South Africa
Being held at the Wanderers Cub, Illovo by the South African Institute of Mining & Metallurgy. The objectives of the conference, which follows a successful event in Perth, Australia, in 2009, are safety enhancements, best practice in underground mining fucussing on development, and new or improved technology. For more information contact Jacqui van der Westhuizen on email jacqui@saimm.co.za, tel +27 11 834-1273/7 or visit http://www.saimm.co.za.

11-12 OCTOBER 2011
3rd Annual Fire Protection and Safety in Tunnels Conf, Salzburg, Austria
Radisson Blu Hotel. Exploring innovations for designing, implementing and upgrading tunnel fire safety, including regulatory updates, cost-effective fire safety projects and successful evacuation. More by emailing Melissarambridge@arena-international.com, tel. +44 (0)207 406 6613 or see www.arena-international.com/fpst2011.

12-14 OCTOBER 2011
Int Conf GeoProjects 2001, Sofia, Bulgaria
Organised by the Bulgarian Association for Geotechnical & Tunnel Construction (BAGTC). Email office@bagtc.com.

16-21 OCTOBER 2011
12th International Congress on Rock Mechanics, Beijing, China
At the China National Convention Centre (CNCC) and organised by the Chinese Society for Rock Mechanics & Engineering (CSRME) with the ISRM national group of Singapore. Themes include site investigation and field observation, rock properties testing, analysis techniques, design methods, rock engineering in hazardous geoenvironments, rock excavation and the underground storage. For general information contact CICCST by email secretariat@isrm2011.com, tel +86-10-62174061 or see www.isrm2011.com.

17 - 19 OCTOBER 2011
13th AFTES International Congress, Lyon, France
This 3-day congress is organised by the French Underground Tunnelling and Underground Space Association (AFTES), with partner associations in Italy, Belgium, Spain, Portugal and Switzerland. Contact AFTES for more information: 15 rue de la Fontaine au Roi, 75011 Paris, Tel : +33 (0) 1 44 58 27 43

18 OCTOBER 2011
5th CityBuild Int Scientific & Technical Conference, Moscow, Russia
Organised by Russian Tunnelling Association at All-Russia Exhibition Centre Hall 75. Themes include underground transport, hydraulic engineering and municipal tunnels with underground space development. Contact Alexander Levchenko by email rus_tunnel@mtu-net.ru, tel +7 495 608 80 32 or see www.tar-rus.

26 - 27 OCTOBER 2011
Underground Infrastructure of Urban Areas, Wroclaw, Poland
Organised by the Wroclaw University of Technology's Institute of Civil Engineering, the Polish Society for Trenchless Technology and the ITA-AITES Polish group, this will be forum on the topics related to building tunnels and underground infrastructure in cities. Contact Andrzej Kolonko, Tel. +48 71 320 2914 or email andrzej.kolonko@pwr.wroc.pl

6 - 8 DECEMBER 2011
STUVA Conference, Berlin
The 2011 biannual conference of non-profit research institute STUVA (the German Research Association for Underground Transportation Facilities) will focus on "Underground Construction for Sustainable Environmental and Climate Protection." New this year is a Youth Forum, an opportunity for young tunnel engineers to present. The winner of the STUVA young talent prize will be selected from the speakers, and awarded at the show. More information available from www.stuva.de Email: info@stuva.de

8 DECEMBER 2011
T&T International Awards 2011, Berlin, Germany
Launch of this event that promises to champion the industry's best efforts, greatest achievements and most impressive recoveries. There are categories on overcoming adversity, sustainability and innovation. For further information on entering and attendance e-mail: awards2011@tunnelsandtunnelling.com

24-26 APRIL 2012
3rd Int Conf on Shaft Design & Construction, London, UK
Organised by the Mining Technology Division of the IMMM and the BTS at 1 Carlton House Terrace. FULL PAPERS DEADLINE 31 OCTOBER. The scope includes all areas of design and construction of both civil engineering project and mine shafts. Contact Paul Harris at IOM Communications by email paul.harris@iom3.org, tel. +44 (0)20 7451 7302 or see www.iom3.org/events/sdc2012.

18-23 MAY 2012
World Tunnel Congress WTC 2012 & 38th General Assembly of the ITA, Bangkok, Thailand
Organised by the Thailand Underground & Tunnelling Group (TUTG) of the Engineering Institute of Thailand, the theme is 'Tunnelling & Underground Space for a Global Society'. Congress Secretariat: Zaw Zaw Aye on tel.: +662 3192 410, Email: secretariat@wtc2012.com or see www.wtc2012.com

BRITISH TUNNELLING SOCIETY

15 SEPTEMBER 2011:
Crossrail
Status update. Latest developments on this major London project. Speaker: Andy Mitchell, Programme Director, Crossrail

20 OCTOBER 2011:
BTS / BGA Joint Event. Towards a Specification for the Ground - The use of Geotechnical Baseline Reports in the UK
Ground References Conditions. Details to follow. Speakers: Mike Black and Darren Page

17 NOVEMBER 2011:
Dulles Airport Rail Tunnel, Washington DC
Dulles Transit Partners is responsible for designing and constructing Phase 1 of the Dulles Corridor Metrorail Project. An 11.6 mile extension of the existing Washington Metro to Dulles International Airport. A central feature of the project is the Tysons Tunnel. The Tysons Tunnel is a twin-bore, two-track tunnel running at 762m in length between portals. The central 534m is being constructed by SCL. Speakers: Dominic Cerulli and Frank Jenkins of (Bechtel) Dulles Transit Partners and Vojtech Gall of Gall Zeidler Consultants

15 DECEMBER 2011:
Cleaner Seas for Sussex
In order to treat the 95 million litres of wastewater generated each day by residents a new wastewater treatment works and 11km of new sewer were required. Now substantially complete find out how more than 11km of 1.8m and 2.4m diameter tunnels and associated shafts and pumping stations were completed. Speakers: Ben Green, Southern Water programme manager and Craig Reade, Costain project manager

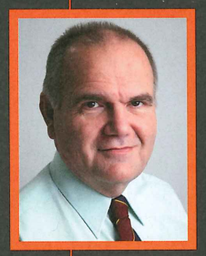
A DATE TO REMEMBER...

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